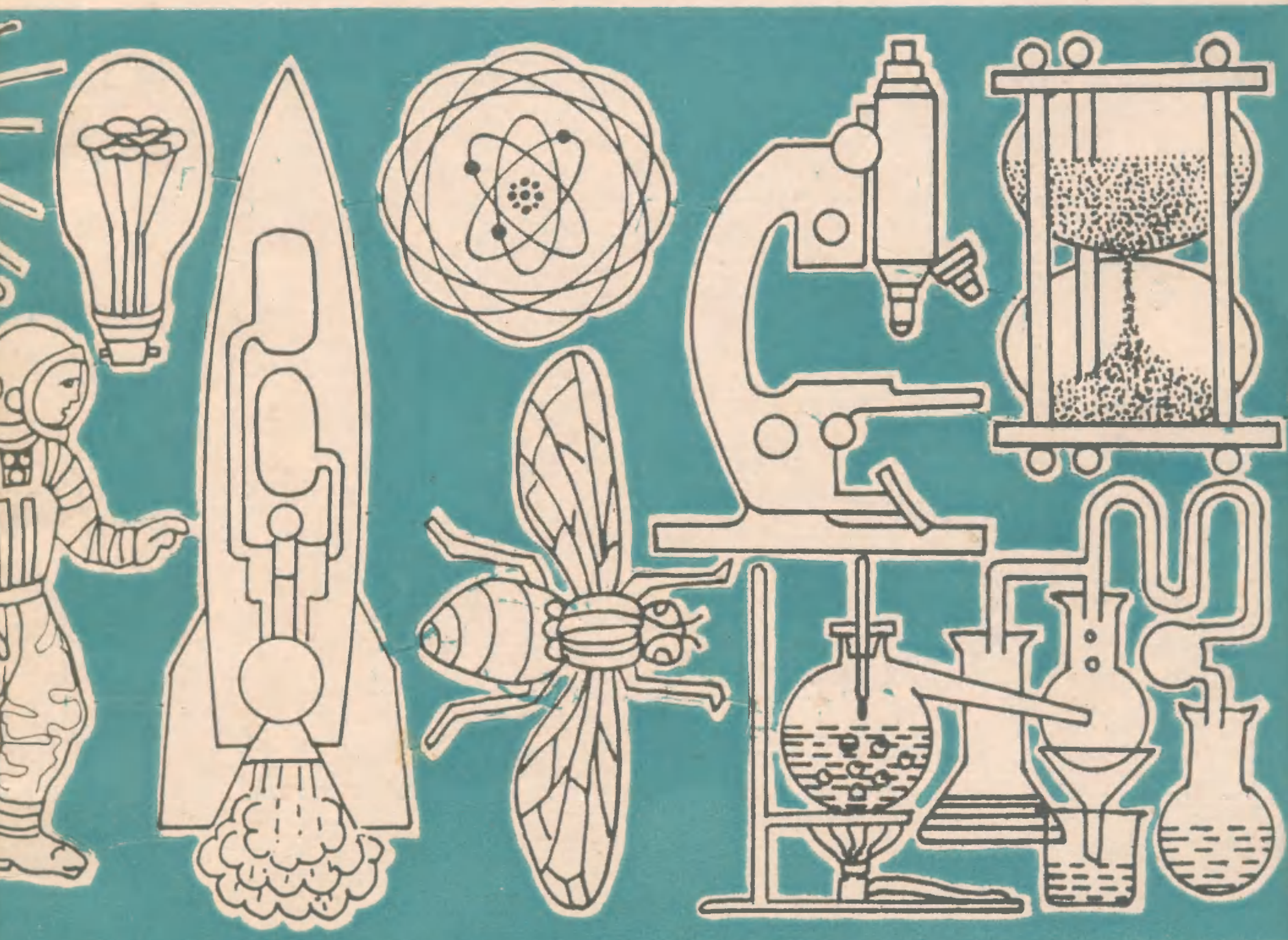
HOW AND WHY IN SCIENCE

SENIOR SERIES: BOOK 2



Edited by R. G. Lagu • Foreword by Homi N. Sethna

HOMI BHABHA CENTRE FOR SCIENCE EDUCATION
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SENIOR SERIES: BOOK 2

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FOREWORD

The purpose of this book is to enable the young students to understand the reasons behind the way things happen in the world around them. It is an attempt to answer some common queries by simple scientific means, and thereby sustain the interest and curiosity of the students in the subject. The book would also help in understanding the reasons behind many more phenomena by cultivating a discipline of scientific enquiry in the mind of the student. Science is a way of thinking that helps us to understand and appreciate nature around us. It is much more fascinating to know why the sky is blue than just to see it as such. Behind each natural phenomenon there is a cause, and science assists us in understanding these causes and their effects. This means we ourselves become the masters of our own environment rather than being at the mercy of nature.

The questions discussed in this book have been raised by children from different parts of the state. The answers and the discussions are designed to motivate them to think and to probe deeper. In some places simple experiments that can be performed anywhere have been suggested.

This book, which is the second in a planned series, will be of immense use to all our young students who have yet to learn about the fascinating tools science has provided in our everyday life.

Bombay,
December 1980

H. N. SETHNA
Chairman, Atomic Energy Commission

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1 How does a chameleon (a kind of a lizard) change its skin-colour?

A lizard is not a very uncommon animal. You might have spotted one in woodlands or in lonely parks. There are many varieties of lizards. Some of them can change the colour of their skin. Generally, lizards living in deserts lack this ability, while those living in forests can easily change their skin-colour. The chameleon is a kind of a lizard which is famous for its ability to change the colour of its skin.

Fig. 1 A chameleon can move its eyes independently.

The skin of every animal is made up of cells which contain coloured substances or pigments. These materials lend colour to the skin. In a chameleon, the colour cells lie in three layers under the transparent skin. The outermost layer consists of yellow and red pigment cells. Under this layer lies another layer which consists of certain crystals that can reflect blue and white light. Finally, the innermost layer comprises cells (melanophores) containing the black pigment 'melanin'. Melanophores have tentacles (small narrow tubes) up through the two layers above, through which melanin granules can rise due to nervous stimulation. It is these cells that control the shades of the colours.

When the chameleon is totally relaxed, melanin granules stay concentrated in the base layer. White light is reflected from the middle layer, and the chameleon looks yellowish or reddish. en the melanop ores are s imula ed, e granules rise up upto the middle layer. White light is therefore not reflected, and the chameleon looks the mixture of blue and yellow (i.e., green) or the mixture of blue and red. When the chameleon is still more excited, the black granules rise up all the way through the tentacles, and the chameleon looks dark brown. In this state, the other two layers are completely obscured.

The chameleon changes colour according to its feelings like fear, anger, etc. The colour also depends upon the temperature of the surroundings. Sometimes the chameleon uses its ability to change colour, in order to escape detection by an enemy. The chameleon makes its skin-colour match the colour of the surroundings, making it difficult for its predator to see it.

Can you guess why the army uniform is olive green?

2. Which is the biggest invertebrate (i.e., an animal without a backbone) in the world?

There are many ways of classifying animals in the world. One way is to divide them according to whether or not they have a backbone. Animals which have a backbone are called vertebrates and those without a backbone are called invertebrates. An invertebrate not only has no backbone, but it has in fact no bones at all. Man, cow, monkey, snake, fish, birds, etc. are

vertebrates, while cockroach, butterfly, ant, earthworm, jellyfish, crab, amoeba, etc. are invertebrates.

The squid is the biggest invertebrate. Please remember that the word 'squid' refers to a large family containing many varieties of squids. A particularly large variety is over 50 feet long, with arms extended. Surprisingly, such a huge creature has no bones at all. It is just like a big sack.

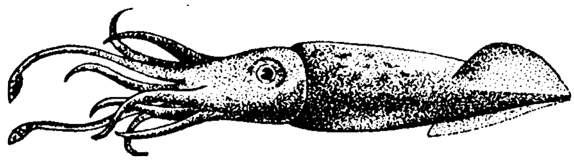


Fig. 2 A squid has two long tentacles and eight arms. It swims by jet propulsion or, more slowly, by using its fins.

The giant squid lives in the sea. It has a novel way of moving about in water. It fills itself with water (it can hold plenty of it) and ejects a jet of water. The reaction of the jet makes it move about. The squid feeds on other animals in the sea.

The squid uses an equally novel method of protecting itself. It has a sac containing a dark ink-like liquid. When the squid senses danger, it ejects a large portion of the dark liquid. The surrounding water becomes dark and, therefore, more or less opaque. The squid makes use of this dark screen to escape from its enemies.

Do you know that in the Second World war, warships used to produce a thick smoke-screen to make good their escape?

3. Why do old people have white hair?

Hair is really a part of the skin. The colour of our skin depends upon five pigments (coloured substances) in our body. Melanin is the most important of these pigments.

Melanin is a dark brown pigment produced in our body by cells called 'melanocytes'. Melanin is stored under the skin, and in the hair and eyes. Since the outer layer of our skin is thin, one can see the colour of melanin stored under it, just as a leaf looks green because of chlorophyll in it.

The amount of melanin under the skin decides the complexion of a person. Less of it leads to a fair complexion, while its excess leads to a dark complexion. Since hair is a part of the skin, the colour of hair also depends upon the amount of melanin in the skin. Similarly, the colour of eyes also depends upon melanin. Generally, people living in hot climates have a dark complexion, black hair and black eyes. You will notice, however, that all people living in hot climates (say, India) are not uniformly coloured. There is some variation in the shades of the colour of the skin, the hair and the eyes. Some people are quite fair, while some others are much darker. Similarly, the colour of hair varies from black to pale brown, and the colour of eyes also varies from black to cat-like grey.

On the other hand, people living in cold climates have usually a fairer complexion, and their hair is light-coloured. Here also, there is a variation from blonde to brunette. Their eyes are usually light-coloured. Generally, you will notice that the complexion, colour of hair and colour of eyes go together.

If the pigment is not uniformly distributed under the skin, patches are observed on the skin. Sometimes, there is an excess of melanocytes in a small region which, therefore, appears darker than the rest of the skin. We call such a small patch a mole.

In old age, all the processes in the body slow down. The cells produce less melanin. That is why the hair slowly turns grey to white. Each hair is like a small transparent tube. As long as it

is full of melanin, it appears dark. When this tube does not get enough melanin, the colour begins to change. The empty tube appears white. You must have seen a refill tube in a ballpen. With blue ink filled in, it looks blue. An empty refill tube, however, looks greyish.

Sometimes, however, cells (melnocytes) lose their ability to produce melanin even in young age. Such a person, though young, will have white hair.

Melanocytes need special materials, called enzymes, to make melanin. If these enzymes are lacking, enough melanin is not produced and some parts of the skin (in addition to hair) appear white. Such a person suffers from leucoderma. Leucoderma is not a contagious disease. It results simply from the lack of melanin. In fact, leucoderma is not a disease. It is merely a condition of the skin.

4. What is bone cancer and blood cancer?

You know that all animals are made up of cells. In every animal, including man, new cells are constantly produced by the division of old cells. In a normal man, cells divide in a regulated manner and only the required number of cells are formed. Sometimes, however, for no apparent reason, cells start multiplying in an uncontrolled fashion. This results in a big lump of cells, which is called a cancerous tumour.

The accident mentioned above can happen anywhere in our body. Terms like lung cancer, stomach cancer, throat cancer, breast cancer etc. refer to the place of the accident and the part of the body that suffers from it.

You know that new cells are also produced in bones. In a healthy bone, new cells are being produced in the inner part, while old cells in the outer part die continuously. In bone cancer, the inner cells keep on multiplying indefinitely, producing a tumour inside the bone. For the tumour to develop, the bone need not be hollow. The tumour can develop in any bone, hollow or solid, big or small.

The tumour exerts pressure from within the bone and can deform it. The deformation exerts pressure on the surrounding muscles and blood vessels, obstructing the flow of blood. As the bone cancer grows, the inside pressure increases, making the bone brittle. The growth causes intense pain. Under these conditions, a small pressure from outside can produce cracks, or even break the bone.

The cancerous tumour is either removed surgically or is burnt and destroyed by gamma rays from a radioactive source like Cobalt-60. In bone cancer, the affected bone is replaced by a similar one made of stainless steel. Sometimes, strong Laser light is used to burn out the growth.

One may also suffer from blood cancer. In all other types of cancer, a tumour develops. However, there is no tumour in blood cancer. When seen through a microscope, the blood of a patient suffering from blood cancer looks quite different. The blood contains an abnormally large number of white blood cells. Often, the patient shows symptoms of anemia. The blood contains less amount of haemoglobin and, therefore, less ability to carry oxygen to different parts of the body.

A person suffering from blood cancer feels weak and drowsy and has a feeling of nausea.

Unfortunately, as yet there is no cure for blood cancer; the only treatment is 'blood transfusion', i.e., to replace the patient's blood by new healthy blood. Since the defect is in the production process of white blood cells, even this remedy is temporary. These blood cells are added continuously to the new blood, requiring transfusion every 2 to 4 months. It is not known, however, why the cells in our body behave in such an apparently strange manner!

5. What is a heart attack? Can it be prevented?

We often hear of persons dying suddenly due to heart attack. In many cases, the death is so sudden that the person dies even before any medical aid could be given.

The heart is an important vital organ in our body. It is a pump made of muscles that contract and expand to pump blood through the network of large and small blood vessels in our body. The blood carries glucose and other nutrients (nourishing materials) which our body extracts from the food we eat. It also carries oxygen which is necessary to burn the glucose to produce energy. Naturally, the heart is busy all the time—from birth to death.

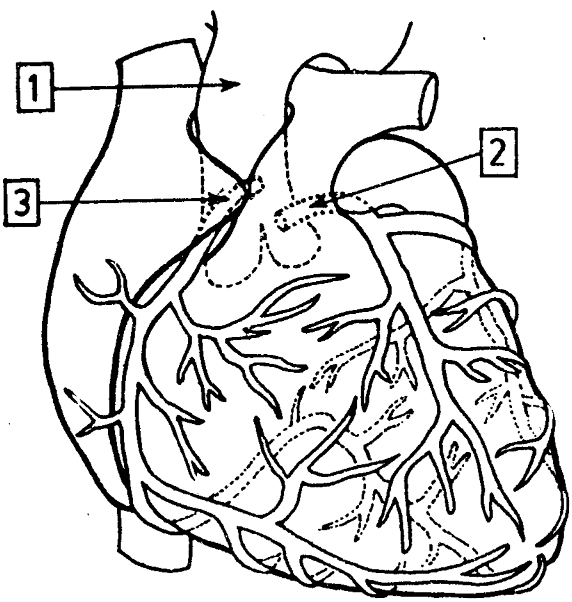


Fig. 3 The human heart. When the heart contracts, blood is pushed out through the aorta (1) and is supplied to the body. Immediately thereafter, when the heart expands, some part of the blood in the aorta flows back into two major coronary arteries (2 & 3) through which blood is supplied to the heart muscles by a network of smaller blood vessels and capillaries.

The heart also needs blood, like any other organ in our body. The heart has to supply blood to its own muscles. When this supply is good, the heart functions properly. There are arteries which supply blood to heart muscles. A heart is like a cashier in a bank who handles a lot of money, but receives only a limited salary.

The term 'heart attack' means the death of a part of the heart muscle due to inadequate supply of blood. The muscles of the heart receive their blood supply through two main coronary arteries which branch off, forming a network of smaller arteries and capillaries through the heart muscles. Sometimes the inner lining of a coronary artery becomes thick and rough, making the artery narrow. You know that fat is one of the constituents (parts) of our food. If we keep on eating food rich in fat, the unused excess fat keeps accumulating in the blood. Excessive fat in the blood gets deposited, forming a lining inside the blood vessels. The vessels, therefore, become narrow and thick. If this happens to a coronary artery, a person still feels normal and healthy if the other 'side arteries' manage to supply adequate blood to the heart muscle. If the blood vessels supplying blood to a particular part of the heart muscle become narrow, rigid and thick, the muscle suffers from a lack of oxygen, but is still getting enough oxygen to remain alive. This insufficiency of blood supply is called 'Angina Pectoris'. Such a person gets pain in the chest, if he exerts himself. A little rest, however, relieves him of the pain. Angina is really the cry-signal of a starving heart. This condition can lead to the formation of a clot in a coronary artery (Coronary Thrombosis). The blood moving with difficulty t..roug.. ...e roug..ene.. ..a..s mak..s it easier for a clot to form. If the clot completely blocks the blood supply to a particular area of the heart muscle, that area gets practically no oxygen and consequently dies. It cannot be made alive by any means. The person may die instantly, or may get severe pain but can still survive, or he may even feel completely normal (silent heart attack). That depends upon where, in the coronary network, the clot is formed.

The symptoms of heart attack are an acute pain in the chest, pain or numbness in the left

arm, and heavy sweating all over the body. In such a case, the patient should be asked to lie down and medical help should be obtained immediately.

Most of the heart attacks can be avoided. Following regular and moderate habits, keeping off habits like smoking, eating simple food not too rich in fats, and regular exercise, provide a reasonable protection against a heart attack.

Children and very young people need not be unduly scared of a heart attack. If you are leading a normal active life, you would probably not suffer one at all. If, sometimes, you do get a pain in the chest, do not get frightened. It is probably due to indigestion or due to gases in the stomach pressing the diaphragm that separates the chest from the stomach.

6. When we enter a semi-dark room after being in bright sunlight, we cannot see things clearly for some time. Why?

We are able to see things in bright light as well as in dim light. The pupil of our eye adjusts its size according to the brightness of light. When the light is not good, the pupil expands (dilates) so that more light enters the eye. When the light is bright, the pupil contracts. You can test this by a simple experiment. If you shine a powerful torch in the eye of your friend, you will see his pupil contracting whether your friend likes it or not. You may also try this experiment on your house-cat, if you have one. Similarly, when we enter a dark room from bright sunlight, the pupil takes some time to dilate. When the pupil becomes wide enough, we begin to see things clearly.

There is another more important reason why things are not immediately visible in the dark. Our eyes are made up of three layers. The innermost layer is called the retina. The retina is composed of cells called rods and cones. The rods

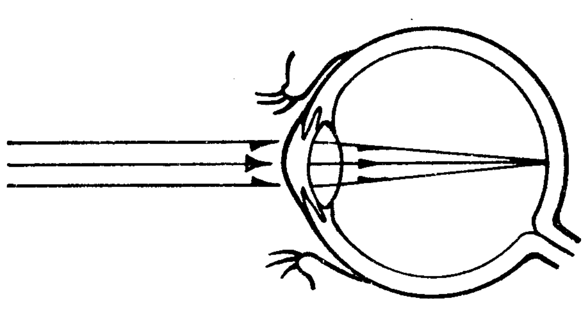


Fig. 4(a) Cross-section of the human eye.

contain a certain purple-coloured substance called 'rhodopsin'. Light from an object falls on the retina and decomposes rhodopsin into two substances. This decomposition sends electrical signals to the brain, and we see the object.

There is, however, a difficulty here! If rhodopsin is continuously decomposed by light entering our eyes, a time should come when the whole stock of this substance is decomposed. We should, therefore, become blind! How is this calamity prevented?

It is true that rhodopsin is continuously decomposed. But then it is also continuously reformed. The retina, therefore, never suffers from a complete loss of rhodopsin. In bright light, our eyes may feel fatigued, but we will never become blind. The decomposition and recombination of rhodopsin goes on continuously in our retina.

In bright light, a lot of rhodopsin is decomposed. If we suddenly move into a dark room, we do not see things clearly because the amount of rhodopsin is reduced. It takes some time for rhodopsin to form again, after which things become visible to us.

We may consider the opposite case. When we suddenly enter into bright light from a dark room, our eyes get dazzled. In the dark, only a [illegible] intact. Sudden entry into bright light decompo-

Fig. 4(b) Flies hover over a plate of sweets. A disturbance makes them fly away. On removing the disturbance, they come again to form small colonies (decomposing and reforming of rhodopsin).

ses a lot of rhodopsin. This process occurs all too suddenly. The brain, therefore, receives an avalanche of signals which it cannot bear, and our eyes automatically close.

Vitamin A is required to produce rhodopsin. Lack of vitamin A causes night-blindness. A man suffering from night-blindness has great difficulty seeing objects in a dimly lit room. This disorder, however, is easily cured by large doses of vitamin A. If you regularly eat plenty of carrots, leafy vegetables etc. which are rich in vitamin A, you will not suffer from night-blindness.

7. Why does water, thrown at random, break itself into round drops? Why doesn't it happen with ice?

Water is a liquid substance. You know that a liquid can be easily broken into small parts. (Here, parts do not mean molecules of the liquid. A small part of a liquid contains millions of molecules). We can easily pour water from a glass, in small portions at a time. We cannot, however, do this for a solid substance like ice. When cooled, water molecules get more and more bound to one another and water freezes to ice. Once the ice is formed, we cannot easily separate the parts. To separate a small piece of ice from a big chunk, one has to use an ice-pick or a hammer!

If we throw a piece of ice, it is not spilt into small parts since molecules in ice are strongly bound to one another. However, when we throw water, it breaks into drops because molecules in water are loosely bound.

A drop of water looks round. Ths is true of all liquids. Mercury spilled on the floor breaks into round drops. A small drop of honey in a dish also looks round. Why does a drop of every liquid look round?

A drop of liquid contains millions of molecules. They try to pull one another towards themselves. The molecules on the surface of a drop attract one another and are pulled in by the molecules which are inside the drop. The result of this molecular attraction is to make the surface of the drop as small as possible. If you make different objects from the same amount of clay—for example, a square block, a cylinder, a sphere or an object with an irregular shape etc. you will find that the sphere has the minimum surface. This means, if different shapes are made from a given amount of material, the spherical

shape has the least surface area. This rule also applies to water drops. The condition of least area for a given volume makes the drops round.

When some other factors are present, the spherical shape is deformed. For example, when a water-drop hanging from a tap begins to grow in size, its spherical shape changes. Due to its own weight it is drawn down. Similarly, a small drop on a glass plate looks round, but a bigger one looks flattened.

8. Why does sound change continuously as a vessel is being filled up with water from a tap?

You know that sound is produced by vibrating bodies. The strings of musical instruments, the membrane of a drum, the air column in a flute, the reeds in a harmonium are some examples of vibrating bodies that produce sound. In fact, when we speak, the vocal chords in our throat vibrate and produce sound.

When a vessel is kept under a running tap, the sound coming from the vessel changes continuously. It is bass (of low pitch) in the beginning and becomes shrill (of high pitch) as the water fills up. How is this sound produced?

The metal vibrates and gives off sound. As the water fills up, the metallic sound becomes weaker. Apart from the metallic sound, another sound comes from the vessel. The water jet striking the surface of water makes the air in the vessel vibrate. The column of air, from the surface of the water to the mouth of the vessel, vibrates and produces sound. We hear changes in this sound.

The sound, which is bass in the beginning, becomes shrill as the water fills up the vessel. A bass sound has low frequency. As the frequency increases, the sound becomes shriller. The frequency of the sound produced by a vibrating air column depends upon its height (or length). A longer air column produces sound of a lower frequency. As the water fills up the vessel, the air column becomes shorter and shorter, and the frequency of the sound increases continuously. Therefore, a sound of increasing frequency, or pitch, is produced as water fills up the vessel.

It was mentioned above that the metallic body of the vessel also produces sound. These vibrations are suppressed (damped) as water fills in. You can conduct a simple experiment to study damping of sound. If you strike an empty metal tumbler with a spoon, a characteristic sound is produced. If you hold the tumbler in your hand and repeat the experiment, a different sound is produced. This sound has a lower frequency and dies down very fast. When a completely empty vessel is placed under the tap, both the sounds (metallic and that due to air column) are produced. The filling water quickly suppresses the metallic sound. The changes in the sound that you hear are mostly due to the decreasing air column.

Do you now understand how an artist playing 'Jalatarang' is able to produce a variety of musical notes, or how different notes are produced by a flutist?

9. How does a big ship made of iron sheets float on water, while a small piece of iron sinks?

A piece of iron or a needle sinks in water. Big ships made of iron, however, float merrily. What makes them float? To be sure, a number of objects sink in water and a lot others float on it. How does one decide whether a particular object will sink or float?

When we throw an object in water, the water pushes the object up. This is called 'buoyancy'. Try pushing an empty sealed can in water. You will feel the upward pressure on your hands. When we dip a bucket in a river, the bucket feels lighter as long as it is under the surface of water and suddenly 'becomes' heavier as soon as we pull it out. Similarly, a wooden block pushed inside the water by hand bobs up and floats, as soon as the hand is removed. You must have seen that the weight of an object tied to a spring balance is reduced when the object is immersed in a liquid. These experiences show us that water pushes up all objects thrown in it.

The earth pulls every object towards itself. This pull is called the 'weight' of the object. An object in water is pulled downwards by the earth and is pushed upwards by the water. If the earth wins in this game of push-pull, the object sinks down; if the water wins, then the object floats.

Every object has density. Water also has density. Whether the object will sink or float is decided by the densities of the object and of water. Density of an object simply means the ratio of its weight (really speaking, mass) and its volume. (To find out the 'density of an object', one does not worry about whether the object is hollow or solid—one simply takes the ratio of its mass and volume. Please remember that the 'density of an object' may come out to be different from the 'density of its material'. Also, the volume of the object is to be found out from the volume of the water displaced). If a brass bob weighs 80 gm and its volume is 10 cm^3, its density will be 8 gm/cm^3. Density of water is 1 gm/cm^3, i.e., 10 cm^3 of water weigh only 10 gm. Since density of the brass bob is more than that of water, the bob will sink.

Now imagine that a flat disc is made out of the brass bob, by hammering it. While doing so, neither the mass of the bob (80 gm) nor its volume has changed. Therefore, the disc, like the bob, will sink in water. Now imagine further that the disc is fashioned into a brass cup. No brass is added or removed in this process. However, the volume of the cup will be much more than the volume of the disc. The volume occupied by the brass is only a small part of the overall volume of the cup. Most of the volume of the cup is occupied by the air inside the cup. Since the mass of the cup has remained the same and its volume has increased, the 'density of the cup' (not the density of brass) is reduced considerably; so much so that it has become less than the density of water. No wonder that the cup, even though made of brass, floats on water.

Whatever is true of a brass disc and a brass cup is also true of an iron sheet and an iron ship. The densities of a steel needle, an iron nail, a solid iron bob etc. are more than that of water —therefore these objects sink. A steel cup, a steel vessel, an iron ship etc. have densities less than that of water—therefore these objects float.

The ball fitted to a ball-cock in a water tank floats on water. This ball is made of copper or brass. It floats because it is almost completely hollow from inside and, therefore, its density is much less than that of water.

These considerations about 'floating' apply equally well to all the things. The density of kerosene is less than that of water. Therefore, kerosene floats on water. Also, a solid iron bob sinks in water but floats on mercury. Do you now see why a balloon filled with hydrogen defies gravity and rises up through the atmosphere? Remember that the density of the balloon (i.e., the mass of the inflated balloon divided by its volume) is less than that of air. Also remember that air, like water, pushes all objects up. (In other words, air also has buoyancy.)

10. Why does paper become more transparent when a drop of oil is placed on it?

The light falling on an object is divided into three parts: reflection, absorption, and transmission. A part of the light is reflected and the rest, which is not reflected, is continuously absorbed in the object. The remaining part, if any, is transmitted out, i.e., it goes through the object.

Before considering the question, let us understand a fundamental principle in physics.

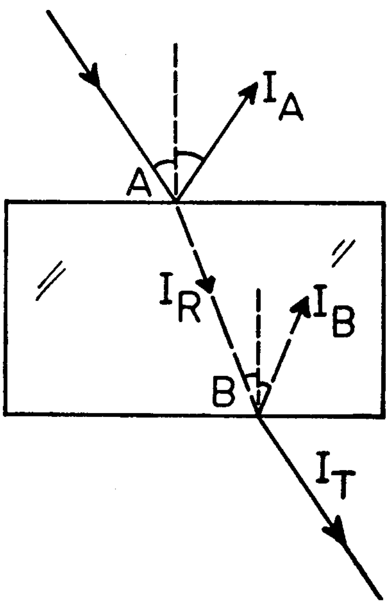


Fig. 5 A ray of light, while passing through a glass block, is partly reflected and transmitted at the points (A and B) of entry and exit.

Suppose a ray of light falls at A on the glass block (see the figure). A part (I_A) of light is reflected and the rest proceeds through the block. At the other side of the block, namely at B, a part (I_B) is reflected and the rest (I_T) comes out of the block. At B, the light intensity (I_R) is split into I_B and I_T.

You may be familiar with a quantity called 'refractive index'. When light goes from one medium into the other, it changes its direction. The refractive index decides the amount by which light will change its course. The refractive index, therefore, depends upon the two media involved. For air, refractive index is assumed to be approximateiy one. The quantity, refractive index, is assigned to every material by comparing it with respect to air. When we say that the refractive index of glass is 1.5, it is given with respect to that of air.

Whenever ligh goes fro n other, a part is reflected at the boundary and the rest goes ahead. This division of the incident light depends upon the difference between the refractive indices of the two media. When the difference is large, the incident light is strongly reflected and only a small part proceeds ahead. On the other hand, a smaller difference between the two refractive indices reduces the reflected intensity and, therefore, the transmitted intensity increases. (When, in the limit, this difference becomes zero or both the media become the same, the boundary vanishes, and the light, therefore, goes ahead undiminished).

In the figure, the light I_R at B is being divided into reflected (I_B) and transmitted (I_T) parts. At B, light is entering from glass into air. Refractive indices of glass and air are 1.5 and 1 respectively. As a result, a certain part is reflected and the rest is transmitted. Suppose the glass block is now immersed in water. Then, at B, light will emerge from glass into water. The refractive index of water is about 1.3. The difference between refractive indices is now 0.2 (i.e., 1.5—1.3), as against 0.5 when the glass block was in air. This decrease means, more light is now transmitted in water and, therefore, less amount is reflected back into the glass block.

Paper, as you know, is made of fibrous material. These fibres are not packed tightly like chalk-stick in a box. The paper fibres are arranged rather loosely or randomly, so that the

paper has a large number of air-pockets in it. When light falls on paper, a part of the light is bounced back from the surface of the paper and the remaining part enters in it. Since paper is not homogeneous, the light inside the paper sees a mixture of two different media, that is, the paper fibres and the air-pockets. The refractive index of air is different from that of the paper material. Therefore, most of the light travelling through paper keeps suffering reflections. Due to these successive reflections, a very small part of light comes through the paper. The paper therefore looks almost opaque. Moreover, since quite a bit of light is reflected, the surface of the paper gets the familiar shine.

Now let us see what happens when a drop of oil is put on the paper. The oil spreads over the paper and soaks a part of it. That is, the oil fills up some of the air-pockets in the paper. Therefore, the light, advancing in the paper, encounters oil and the paper material, instead of air and the paper material. The refractive indices of oil and the paper material are much nearer to each other than the refractive indices of air and the paper material. Because of the smaller difference in the two refractive indices, very small amount of light is reflected back and a large portion of light passes through. Therefore, the paper becomes translucent (i.e., less opaque). You would also notice that the oil-soaked paper loses some of its shine and appears dull. Can you guess why ?

You can see this effect in everyday life. The shirt you wear is not transparent. However, when you get drenched in the rain, you can see your skin through the shirt soaked with water.

If a part of a coloured cloth is made wet, the colour of that part looks deeper than the rest of the cloth. Can you tell why?

11. Suppose a ball is thrown up in the compartment of a running train, where would it fall?

You may be tempted to answer that the ball will fall behind the person who throws it. You may think that, after all, the ball takes some time to go up and come down. During that time, the person would be carried forward by the train. Naturally, you would think that the ball should land behind him.

Well, instead of arguing, why don't you perform this experiment the next time you ride a train? You will be surprised to find that the ball lands right in your hands, as it does on a playground. What was wrong with your earlier argument?

In a running train, all the objects in the train acquire the motion of the train. Thus, the fans, the suitcases, the passengers, yourself and the ball in your hand, all move with the speed of the train. When you throw the ball up, it does not lose the motion it had acquired from the train. It continues to move along with the train and, therefore, with you; only, it acquires a vertical motion in addition to its horizontal motion. Thus, the ball, while moving up and down, also travels horizontally, keeping pace with you. The ball, therefore, lands smack in your hands.

In the train, you do not see the ball moving horizontally with you since it keeps pace with you. You only see it going up and coming down. How would the motion of the ball appear to someone outside the train? Consider, for example, a man standing on the ground outside, watching your experiment. As stated above, the ball possesses two motions at the same time—the horizontal motion of the train and the vertical motion given by you. Both these motions together make the ball travel along a parabolic path. An outside observer would, therefore, see the ball mov-

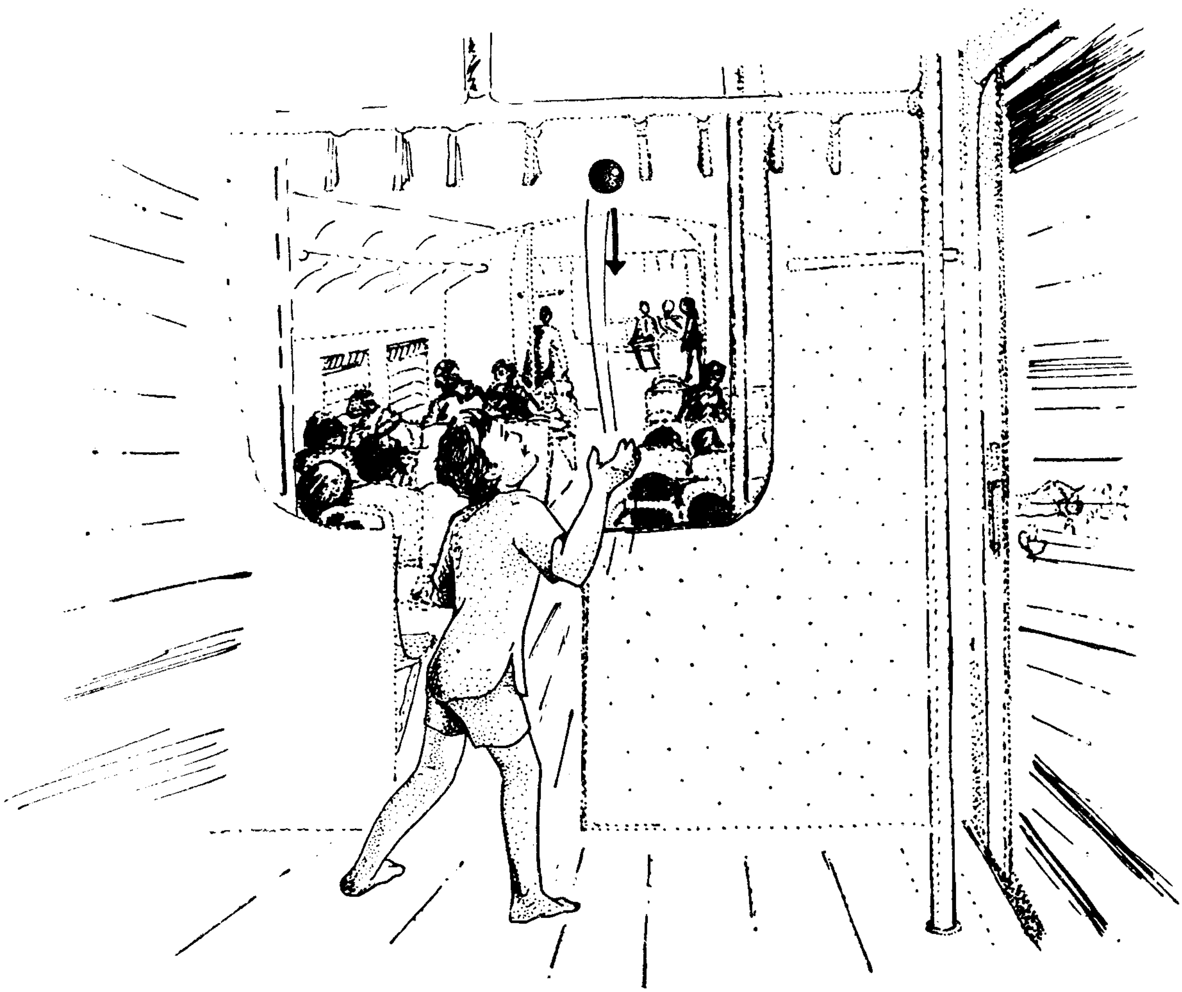


Fig. 6(a) To a man in the train compartment, the ball goes up and down.

ing along a parabolic path. An inside observer (that is, you and your friends travelling with you) would, however, see only the vertical motion of the ball.

Does the ball travel up and down, or does it move along a parabolic path? Which one is the correct description? Well, all motions are relative to the observer. There is no such thing as absolute motion. The motion of the ball, in the experiment discussed above, would be described differently by you and by the person standing outside on the ground. Both the descriptions are equally correct.

You are surprised when the ball lands in your hands in a moving train. You are not surprised, however, when the same thing happens on a playground! Remember, the earth is spinning around its axis, completing one spin every day. It is also rushing through space, in its motion round the sun. Something whispers in your ears, 'As you throw the ball up, you are carried forward by the moving earth and the ball lands

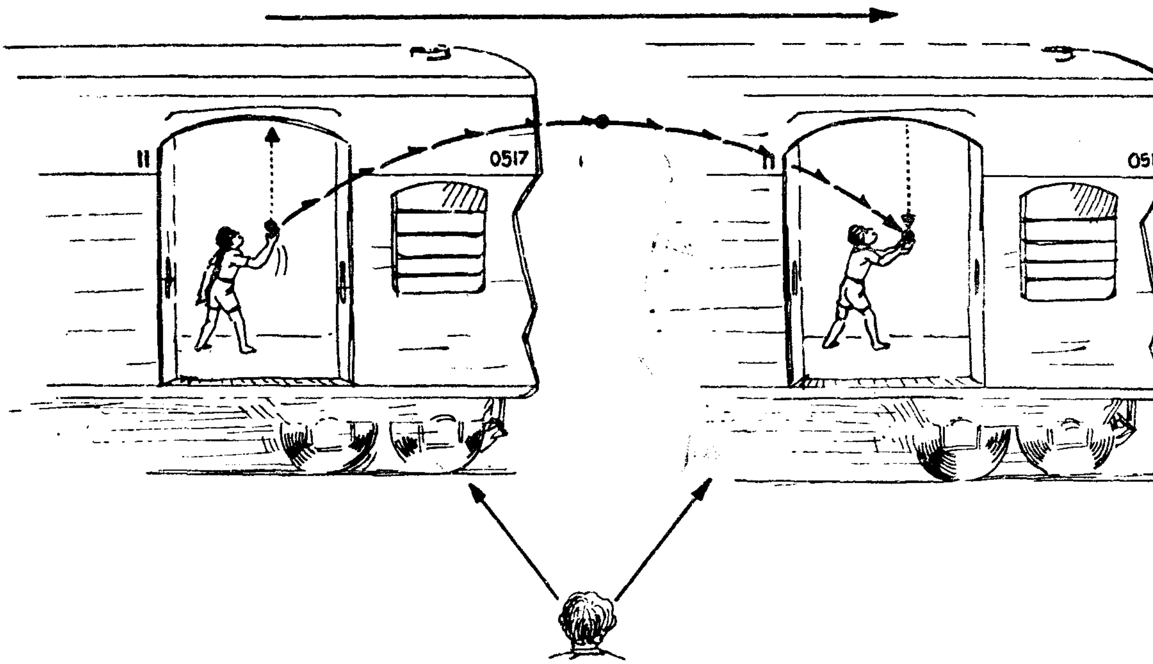


Fig. 6(b) To a man on the ground outside, the ball moves along a parabolic path.

behind you'. Do you now see that the 'something' was misleading you?

Let us take one more example. Suppose a boy is standing in a rain that is coming down vertically. The boy is holding a hollow tube, He finds that when he holds the tube vertical, the raindrops go through unobstructed. In other words, from the way he holds the tube for the drops to go through, he finds out the direction of the rain. As he starts running through the rain, he finds that now, to let the drops go through the tube, he has to hold it slant [see Fig. 6(c)]. Therefore, he concludes that the rain is falling at a slant. Remember that in these two observations nothing happened to the rain itself. The motion of the raindrops was described differently because the observer himself started moving. Thus the description of a motion changes according to the motion of the observer.

If you remember that all objects on the earth are moving along with the earth, you will understand why some of our childhood dreams are not practicable. Children sometimes suggest an inexpensive way of travelling from Vishakhapatnam to Bombay. Take a gas balloon and rise to, say, 1000 metres above Vishakhapatnam. Watch the earth spinning below. When you find yourself above Bombay, release the gas. And there you are in Bombay after a smooth, comfortable and free journey. Yes indeed! However, this trip is planned without realizing that objects on the earth, including those gone in the air, move along with the earth. Your balloon, if kept steady (i.e., if it does not drift with the wind), will remain over Vishakhapatnam all the time. That is why high-powered jet engines, using large quantities of expensive fuel, have to be used for air travel.

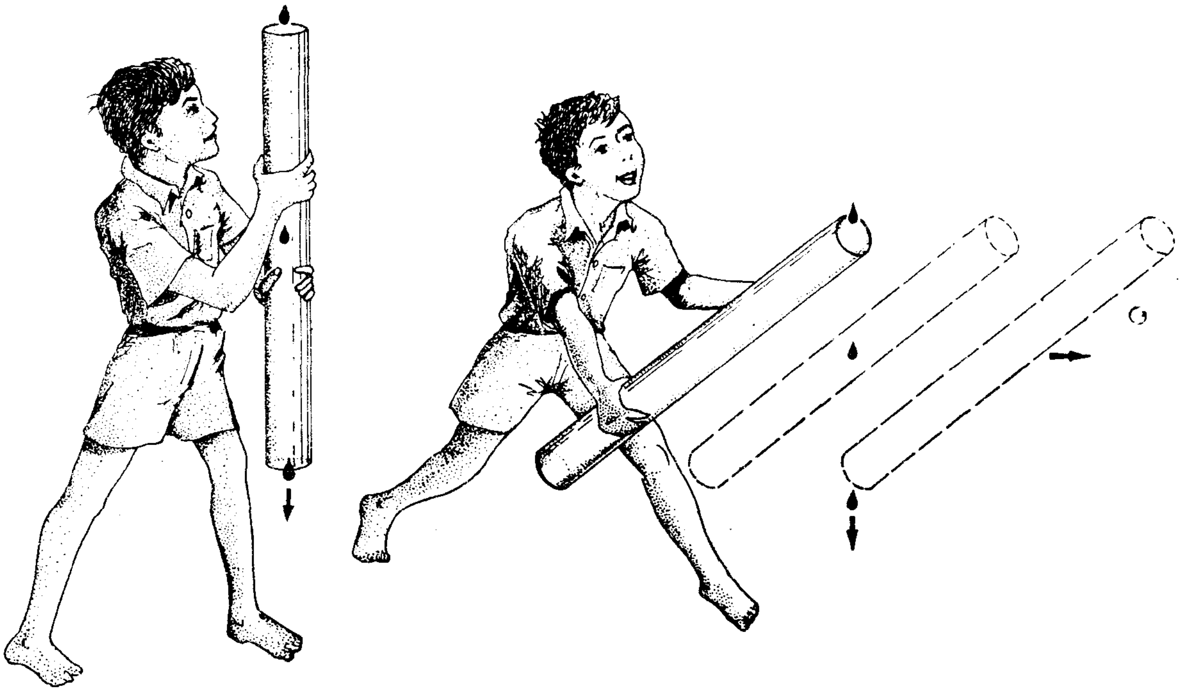


Fig. 6(*c*)

12. How does a tape recorder work?

A tape recorder is a device which records and reproduces sound. This device makes use of a few principles of electricity and magnetism. Let us see what these principles are.

An electric current always produces a magnetic field. If the current is passed through a coil, a magnetic field is produced inside and around the coil. If an object made of iron is placed inside the coil, the object is magnetized. How long would the object retain its magnetism after the current in the coil is switched off? That depends upon the nature of the iron. Soft iron loses all its induced magnetism as soon as the current is switched off. Steel and some oxides of iron, on the other hand, retain their magnetism for a long time after the current is switched off.

One more principle which is used in a tape recorder is called the electromagnetic induction. This principle describes the production of an electric current with the help of a coil and a magnet. If a magnet is moved to and fro along the axis of a coil, an electric current is generated in the coil. The same result is obtained even when the coil is moved, keeping the magnet steady.

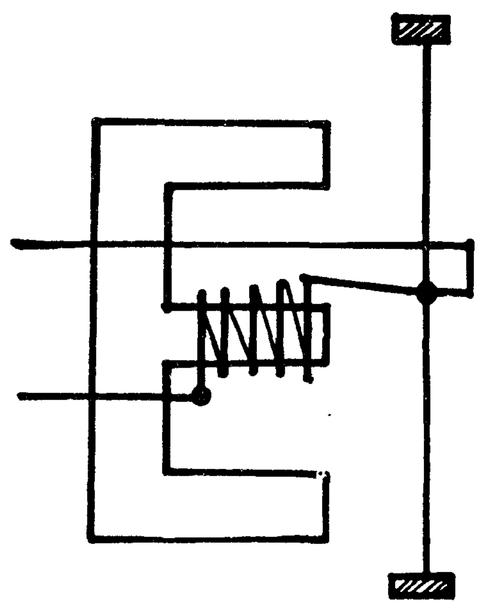


Fig. 7(a) Diaphragm, and the coil wound over a permanent magnet, in a microphone.

You probably know that the tape used in a tape recorder is often called a magnetic tape. This tape is prepared by coating a thin layer of iron oxide, usually red iron oxide (gamma-Fe_2O_3), on a plastic ribbon. Sometimes a blackish looking oxide of iron, Fe_3O_4, is also used. It is the oxide particles on the tape which play an important role in recording and retaining the sound.

Sound is fed to the tape recorder using a microphone which is either built into the tape recorder or is attached externally. The microphone converts sound into a varying electric current. If you observe a microphone carefully, you will notice a screen, a mesh or some thin membrane, attached to a coil. The coil is wound round a permanent magnet. When you produce sound in front of the microphone, the screen vibrates. The vibrating screen makes the coil move to and fro in the field of the permanent magnet. An electric current is, therefore, induced in the coil. This current, being very weak, is fed to the amplifier which increases the strength of the current. The strong current is then fed to the coil of a recording head.

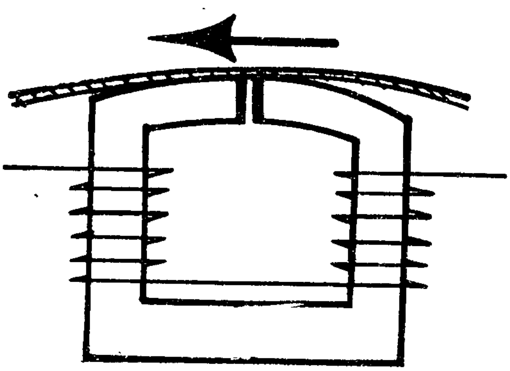


Fig. 7(b) Recording head. The tape passes across the gap. The coil is wound over a soft iron piece having a horse-shoe shape.

The recording head is the part of the tape recorder where actual sound recording takes place. The recording head consists of a soft iron piece having a horse-shoe shape, and a coil wound round it. The horse-shoe has a very small gap. The flow of electric current through the coil magnetizes the soft iron piece, converting it into a temporary horse-shoe magnet. The strength of magnetization depends upon the strength of the current which in turn depends upon the intensity of the sound received by the microphone. When the magnetic tape passes across the gap in the horse-shoe, a part of the iron oxide layer on the tape gets magnetized. You will see that the strength of magnetization depends upon the intensity of the sound.

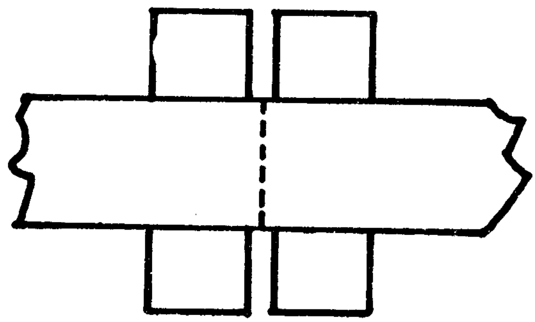


Fig. 7(c) The tape must pass unfolded or uncurled across the recording head gap.

To replay the recorded sound, the tape is rewound and run forward once again at the same speed. The processes described above are now reversed. Please remember that during replaying, the microphone is switched off. When the tape moves across the gap in the recording head, a current corresponding to the strength of magnetization on the tape is produced in the coil. This current is then amplified by an amplifier and fed to a loudspeaker. The loudspeaker converts the changing electric current in the voice-coil into sound waves, reproducing the sound which was recorded earlier.

One of the major advantages of a tape recorder is that the same tape can be used again and again. When the tape, on which the sound is already recorded, is used again for a new re-

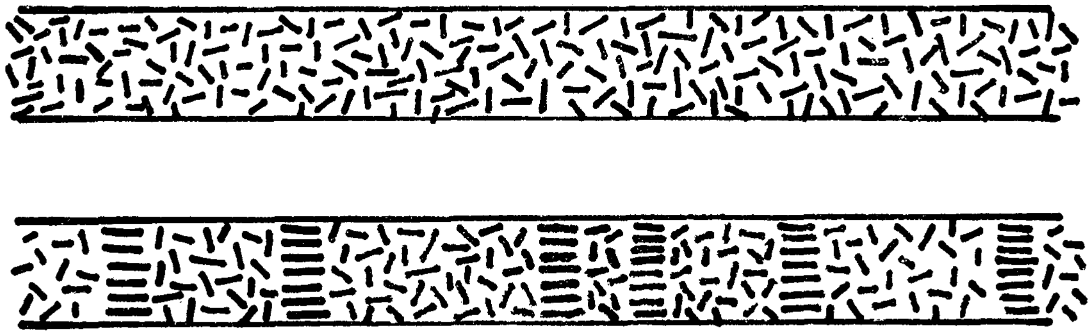


Fig. 7(d) Magnetic tapes have a coating of needle-shaped particles. Upper tape is clean, with particles oriented in all directions. Lower tape has sound recorded at places where the particles are aligned.

cording, each part of the tape is automatically erased before it passes across the recording head. The new signals from the microphone then re-magnetize the tape in a suitable manner.

The performance of a tape recorder depends upon some important factors. The speed with which the tape moves across the head should remain constant. This is achieved by a carefully designed electric motor (and the associated rotating parts) which drives the tape at a constant speed. Also, to record the sound properly, it is necessary that the tape does not fold or curl as it passes across the head.

13. How do fire extinguishers work?

As you know, burning is a chemical process in which the burning material combines rapidly with oxygen. Burning releases a lot of heat and light. All substances are not combustible (i.e., they are not able to catch fire). For example, water does not catch fire. On the other hand, many substances that we use in everyday life, like paper, hay, wood, cloth etc., catch fire. You must have read that, in summer, large stocks of hay are often destroyed by fire. It is therefore necessary to properly store combustible materials and to extinguish fire as soon as it starts. How does one go about extinguishing a fire?

Well, you know that fire requires some material that can burn and a good supply of oxygen. Cutting off the supply of oxygen and removing other combustible materials to a safe place, so that the fire does not spread, are the basic principles. There is one more factor which is also important. The book that you are reading is made of paper and there is enough oxygen in the room. Why doesn't the book catch fire? A combustible material catches fire only if its temperature is above its ignition (fire-catching) temperature. Below that temperature the material does not burn. Lowering the temperature, i.e., cooling the burning material, therefore, also helps in putting out fire.

One of the most common methods of putting out fire is to pour water on it. Fire-fighting engines of the fire brigade use large hoses to direct jets of water on burning houses to control fire. Here, water performs an important job. It absorbs heat and, therefore, brings down the temperature of the burning material. Also, water sprayed on neighbouring houses prevents the fire from spreading.

However, it is not always possible, and fortunately not necessary, to call the fire brigade, every time there is a fire. You must have seen that many buildings, factories, buses, school

laboratories, cinema houses are fitted with red cylindrical or conical gadgets called fire extinguishers. How do these work? They work on the same principles as described above. Only the mechanisms differ in different types of extinguishers.

The simplest type of a fire extinguisher contains carbon dioxide gas filled under high pressure. The pressure is so high that some of the carbon dioxide is turned into liquid. As soon as the plunger of the extinguisher is drawn out, a jet of carbon dioxide gas comes out. The forceful jet is directed at the fire. A cloud of carbon dioxide gas, being heavier than air, replaces the oxygen surrounding the fire. The supply of oxygen to the burning material is thus cut off and the fire put out. Remember that carbon dioxide does not support combustion or burning.

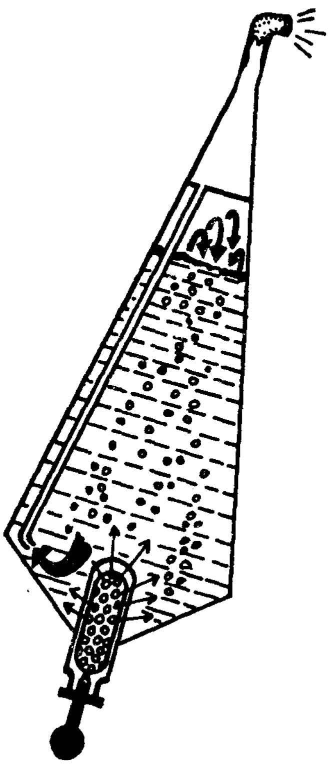


Fig. 8. A water type fire extinguisher containing a solution of sodium bicarbonate in water and a bottle of concentrated H_2SO_4. CO_2 is produced which pushes out a jet of water that puts out the fire.

There is another type of extinguisher which makes use of carbon dioxide gas to force out a jet of water. However, it does not contain readymade carbon dioxide. It contains chemicals like sodium bicarbonate and sulphuric acid that produce carbon dioxide when mixed. A solution of sodium bicarbonate in water is filled in a cone-shaped container which also holds a sealed bottle of concentrated sulphuric acid (see Fig. 2). When you want to use the extinguisher, you simply hit the plunger against a wall. The plunger breaks the bottle of sulphuric acid, so that the two chemicals are mixed and a lot of carbon dioxide gas is produced. The mixture of chemicals under high pressure of carbon dioxide is forced out in the form of a jet. Since the jet contains mostly water, it absorbs heat from the burning material and the fire is put out.

The supply of oxygen to the fire can be cut off by a variety of means. For example, a thin layer of foam or of fine powder around the burning material would achieve the purpose of depriving the fire of its oxygen supply. Two other fire extinguishers, the foam extinguisher and the dry chemical powder extinguisher described below, make use of this technique. Their names indicate the materials used for surrounding the fire.

Foam type fire extinguishers contain chemicals for producing foam. One model of a foam extinguisher contains solutions of sodium bicarbonate and aluminium sulphate stored separately. At the time of using the extinguisher, these chemicals are mixed by an appropriate mechanism. As the mixture comes out of the extinguisher, it comes in contact with air and produces foam. The foam is directed at the fire.

Another type of fire extinguisher, that is, the dry powder type extinguisher, consists of a cylinder filled with dry and finely powdered extinguishing agents like sodium bicarbonate, mono-[illegible]nium p[illegible]sp[illegible]a[illegible] e[illegible]c. [illegible] filled in the container under high air pressure. In case of a fire, you press the knob on the nozzle of the extinguisher which then sprays the pow-

der on the fire. The layer of the powder retards burning and helps in putting out the fire.

When nothing is available and the fire is small, one puts sand or earth on the fire.

Do you know what happens when fire starts in a thick forest? Fire engines can hardly go there, nor is enough water available around. In such cases, the fire is merely isolated either by removing all the dry stocks around it or by chopping down some trees, if necessary.

Another interesting example of extinguishing a fire is to use 'fire' itself! When an oil well catches fire, a big explosion, using powerful explosive, is sometimes made to collapse the walls of the well!

14. Why is a diamond so hard and sparkling?

Do you know that the hard and sparkling diamond is chemically just a collection of carbon atoms? A piece of diamond heated upto 700°C will burn like a piece of coal, producing carbon dioxide (CO_2). It is, however, an expensive experiment!

You may wonder why charcoal, which is also mainly carbon, and diamond have such diametrically opposite physical properties. For example, they differ so much in appearance, hardness and of course cost! Charcoal is soft — it blackens your hand. Diamond, on the other hand, is extremely hard; in fact, it is the hardest natural substance known in the world. What makes diamonds so hard?

Whether a substance will be hard or soft depends on how strongly its atoms or molecules are held together. The stronger they are bound, the harder is the substance. Atoms of the metal tungsten, for example, are held together strongly, making it very hard. Loose binding of atoms, on the other hand, makes the substance soft. Sodium, Potassium, Calcium, etc. are some examples of soft materials. A small force can separate parts of a soft object (remember coal blackens your hand by a mere touch). A considerably stronger force is needed to break hard objects like a stone, a piece of iron, or the precious diamond.

Apart from the strength of the force with which the atoms or molecules are held together, the arrangement of these atoms or molecules in the substance is also important. Consider a pack of playing cards. Each card is flimsy and can be easily torn. But you cannot possibly tear off a pack of 52 cards! Remember, however, that you can slide or shuffle them easily. There is a variety of carbon, called graphite, which is made like a pack of cards. Atoms of carbon in each layer are held together very strongly; but the layers can slide over each other very easily. That is why graphite is used as a lubricant. An ordinary piece of charcoal is merely a collection of loosely bound carbon atoms. It can therefore be broken very easily along any direction.

Diamond is not a heap of atoms like a piece of charcoal, nor is it a layered structure like graphite. It has, rather, a three dimensional network of carbon atoms held together strongly in all directions. That is why diamond is so hard.

Look at the structure of diamond [see Fig. 9(a)]. Here, each carbon atom is bound to four other carbon atoms. The binding between carbon atoms is strong. In addition, these atoms are situated in different planes. To be precise, carbon atoms in a diamond are arranged tetrahedrally, with each carbon atom at the centre and four other carbon atoms at the corners of a tetrahedron. A diamond piece is thus a network of repeated tetrahedra sharing neighbouring atoms, giving it enormous strength. If you

observe the diamond structure carefully, you will notice that it is not a heap of separate tetrahedra. Any given carbon atom belongs to several neighbouring tetrahedra (can you count how many?). This peculiar arrangement makes the diamond one of the hardest materials.

Diamond, as you know, is precious. It is prec ous ecause t s so rare. It s rare ecause the peculiar arrangement of carbon atoms described above can only be achieved under enormous pressures and at very high temperatures. Such conditions exist about 400 km. down inside the earth. Naturally, diamonds are formed in deep mines. Nowadays diamonds can be made in a laboratory, by subjecting graphite to high temperature and pressure.

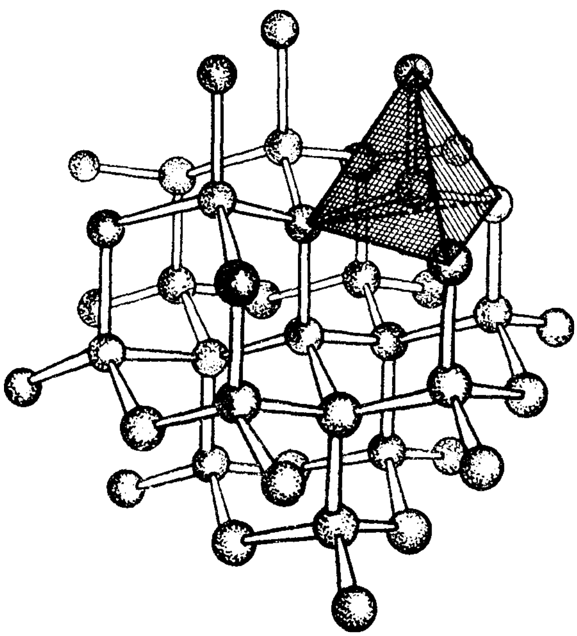


Fig. 9(a) Diamond structure. Spheres represent carbon atoms.

Diamond, as found in a mine, is a hard transparent object. It does not have the lustre that you see on diamonds in a jeweller's shop. How does a diamond acquire the lustre? Remember, diamond has a very high refractive index (approximately 2.4 as compared to 1.5 of glass). Skilled workers cut the natural diamond, using special tools, so that it acquires many plane faces (facets). Light entering into such a piece of diamond suffers many total internal reflections (at A, A′, B, B′ in the figure) before emerging out. It is this property that gives the diamond its peculiar lustre and charm.

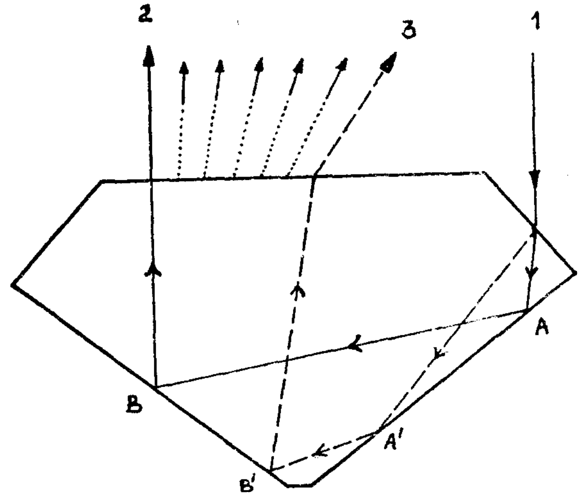


Fig. 9(b) A ray of white light (1) entering a diamond is totally internally reflected at A, A′, B and B′. It is also broken up into rays of different colours which emerge out (2 to 3). This makes the diamond sparkle with brilliant colours.

What is the role of total internal reflection? A beam of light suffers total internal reflection, only if it strikes the surface at an angle greater than the critical angle. The critical angle (Θ) depends upon the refractive index (μ) of the medium. In fact, Sin $\Theta = \frac{1}{\mu}$. A substance of higher refractive index has a lower value for the critical angle (Θ). Since the refractive index of diamond is as high as 2.4, its critical an le is as small as about 25 degrees. (For water, the refractive index is only about 1.3 and, therefore, its critical angle is as large as about 50 degrees.) Since diamond has a very high refractive index, most of the light that enters a diamond suffers several total internal reflections before emerging out of any face. That is why diamonds are so sparkling and beautiful.

Diamond has several uses too! It is used for cutting glass—another hard substance. It is also

used for generating very high pressures. Two diamonds can be pressed together very hard. They won't give way. Scientists use this fact to study the properties of materials subjected to high pressures. Some of the boring drills have diamond tips. These drills can bore holes even in rocks. Diamonds used for such purposes are called industrial diamonds. They are black in colour!

15. A piece of ice is floating in a glass-tumbler filled with water upto the brim. Will the water overflow after the ice melts?

You know that all substances expand when heated and contract (shrink) when cooled. However, the mass of the substance, whether hot or cold, remains the same.

Let us consider melting. When a solid melts, its volume in the liquid state is usually more than its original volume in the solid state. Since the mass remains the same, the above statement means that solids are generally denser (heavier) than their liquids. You must have seen hair-oil freezing on a cold winter day. As part of the oil freezes, the frozen part sinks in the oil. Water, however, is an exception to this rule. When water becomes ice, its volume increases. Since the mass does not change, ice, which occupies more volume for the same mass, is lighter, that is less dense, than water. Naturally, ice floats on water. In fact, whenever you see an object floating on a liquid, you can be sure that the density of the object is less than that of the liquid.

Density is defined as $\left(\frac{\text{mass}}{\text{volume}}\right)$. Density of water is 1 gm/cm^3; that is, 1 cm^3 volume of water weighs 1 gm. The density of ice is only 0.9 gm/cm^3; that is, a block of ice measuring 1 cm x 1 cm x 1 cm weighs 0.9 gm. Now let us recall the law of floating objects. When an object floats (say) in water, the weight of water displaced by the immersed portion of the object is equal to the weight of the entire object. For example, a block of wood measuring 10 cm x 10 cm x 10 cm will sink upto 5 cm in water, since its density may be 0.5 gm/cm^3.

Now, consider a block of ice floating in a glass-tumbler completely full of water. For making the calculations easier, let us suppose that the block of ice measures 1 cm x 1 cm x 1 cm. Since the density of ice is 0.9 gm/cm^3, it will weigh 0.9 gm and will sink 9 mm under the surface of water, leaving 1 mm above. Therefore, the volume of water displaced by the immersed portion of this block of ice will be 1 cm x 1 cm x 0.9 cm, that is, 0.9cm^3.

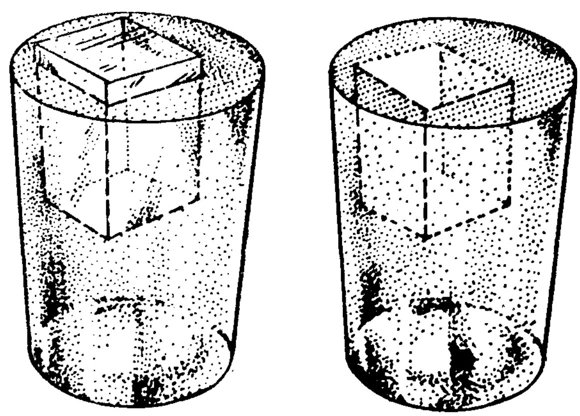


Fig. 10 The ice block melts and collapses into the cavity corresponding to its immersed portion — not a drop spills out.

When the block of ice melts, it will be converted into 0.9 gm, that is, 0.9cm^3 of water which is equal to the volume of the immersed part of ice. The water formed from the entire ice block will, therefore, be accommodated in the space occupied by the immersed portion of the ice block. (The ice block, while melting, will collapse, as it were, into the space of its immersed part.) Naturally, no additional water will be displaced in this process and, therefore, not a drop will spill out.

16. Is it possible to create matter out of energy, according to the relation $E = mc^2$?

Albert Einstein discovered the relation $E=mc^2$, between energy and matter. This discovery made a great revolution in the world of science. In this relation, E is the energy, m is the mass and c is the velocity of light. Since the velocity of light is very large, namely, 3×10^5 kilometres per second, the relation tells us that a small mass, when completely converted, would release a tremendous amount of energy. For example, if an object with a mass of just 1 gm is completely transformed, an energy equal to about 2×10^{13} calories would be liberated. If we use this energy to heat water, it will make steam out of all the water filled in a tank, 60m x 60m x 10m. You can imagine, from this example, how vast the whole affair becomes, from just a tiny piece of matter!

This relation does not, however, tell us how to convert matter into energy or energy into matter. It merely tells us that if we succeed in making this transformation, the result will be according to the relation $E = mc^2$.

Now, there are many examples of matter being converted into energy. When an atom splits (fission), energy is released. Here, a part of the mass is converted into energy. Energy released in an atomic explosion, energy obtained from atomic reactors, energy emitted by the sun are some examples of a part of the mass being converted into energy.

One way to get energy is to split uranium atoms in a reactor. An atom of U^{235} can split in various ways. In one of these, it splits into barium and krypton atoms. This is achieved by a neutron. When a neutron strikes a U^{235} nucleus, the neutron is absorbed and the uranium nucleus breaks into barium and krypton nuclei. During the fission, a large amount of energy is liberated. At the same time, new neutrons are released. The sum of the masses of barium, krypton and the released neutrons comes out to be smaller than the sum of the masses of the uranium atom and the incident neutron. The difference, say (Δ m), in the two masses, i.e., the original mass minus the resultant mass, is completely converted into energy (E) according to the relation, $E = (\Delta m)c^2$.

The process responsible for the continuous release of solar energy is the opposite of fission. The sun has a large stock of hydrogen. At the high temperature of the sun, four hydrogen nuclei (i.e., protons) combine to form one nucleus of helium. The mass of the helium nucleus is less than the total mass of the four hydrogen nuclei. The difference between the two masses is converted into solar energy.

In all these examples, only a part of the initial mass is converted into energy. However, there is one example in which all the mass is converted into energy. This, of course, is an example from a laboratory. You know that every atom has electrons revolving round the central nucleus. Electrons are fundamental particles. Scientists have so far discovered about 30 to 40 fundamental particles. An electron is one of them. You know that an electron carries, a negative charge. There is another kind of a particle, called positron, among fundamental particles. A positron is exactly like an electron, except that it carries a positive charge. It is the twin brother of the electron. You know that unlike charges attract. An electron and a positron, therefore, try to come near each other. When they collide, both of them completely disappear and the energy corresponding to the sum of their masses is released in the form of gamma rays. (To this, of course, we must add kinetic energies of the electron and the positron. However, this is a very small amount of energy as compared to that produced from the masses. We may, therefore, as well ignore it.) This conversion takes place according to the relation, $E_{released} = (\text{mass of electron} + \text{mass of positron})\, c^2$.

We can also see the opposite process in a laboratory. Under certain conditions, a gamma ray completely disappears and a pair of an elec-

tron and a positron comes out from the point of disappearance. When these particles pass through a strong magnetic field, they are pulled in opposite directions. We can, therefore, quite clearly see their tracks in a photograph. Here, energy is transformed into matter (and only a little part remains as kinetic energies of the particles). This transformation also takes place according to the relation $E = mc^2$.

Please remember that from this relation we cannot find out any method of converting energy into matter or vice versa. If we have a stock of energy, the relation simply tells us how much mass we can produce from it. It does not even tell us whether the resulting object will be a pencil, a mango or just some elements.

17. What is an atom bomb? How does it explode?

The world knew about the atom bomb when it was dropped on the city of Hiroshima in Japan, on August 6, 1945. Three days later, on August 9, 1945 another bomb was exploded over the city of Nagasaki. These two bombs completely devastated the two cities in Japan, killing thousands of people and destroying considerable property. Japan surrendered and the war ended. The bomb dropped on Hiroshima was a uranium bomb, while the one that exploded over Nagasaki used plutonium as a fuel.

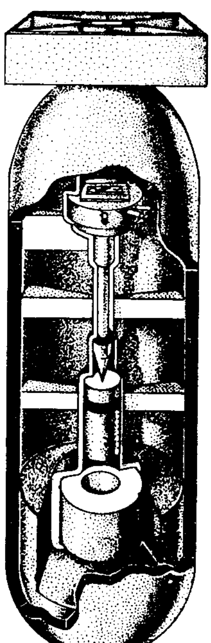


Fig. 11(a) Hiroshima bomb. Two uranium pieces fired into each other.

The term explosion is used to describe a sudden release of huge quantities of energy. That is precisely what happens in an atomic explosion. Let us see what happens when a uranium 235 (U^{235}) or a plutonium 239 (Pu^{239}) bomb explodes.

Natural uranium, that is, uranium as found in nature, consists of a mixture of three isotopes of uranium. Please remember that isotopes of uranium (or of any other element) would have the same chemical properties. Isotopes, therefore, cannot be separated by chemical methods. They differ only in their atomic weights. The three isotopes of uranium are U^{234}, U^{235} and U^{238} Of these, only U^{235} is useful for exploding the bomb. Unfortunately, the percentage of U^{235} in natural uranium is extremely small, i.e., as low as 0.7%. Moreover, the percentage difference of masses in the uranium isotopes is very small—only 3 in 235. It is, therefore, difficult and expensive to separate U^{235} from natural uranium which consists mostly of U^{238} Such a separation, of course, is necessary for making a uranium bomb. It is not necessary to have 100% pure U^{235}. About 90% U^{235} (rest being U^{238}) is enough to make the bomb. Let us see how U^{235} is used for producing an explosion.

When a neutron strikes the nucleus of U^{235} it is absorbed. Immediately, U^{236} nucleus undergoes so much deformation that it splits into two nearly equal nuclei (e.g., Barium and Krypton). In this process, it also emits 2 to 3 neutrons. As you know, the sum of the masses of all these

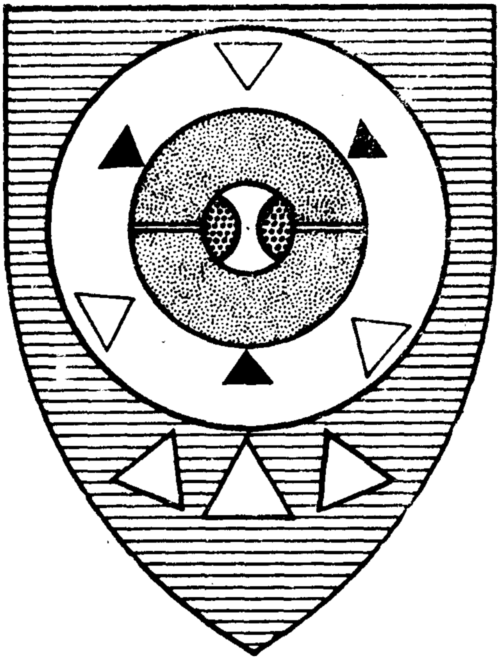


Fig. 11(*b*) *Nagasaki bomb. Two plutonium hemispheres with a central cavity and the surrounding platinum sphere. Plutonium hemispheres imploded by TNT charges to reach the critical stage.*

products is less than the sum of the masses of the U^{235} nucleus and one neutron. This difference in mass is converted into energy, according to the relation $E = mc^2$

If the process described above is applied only to one nucleus of U^{235}, very little energy would be produced. Consider, however, a lump of uranium, mostly of U^{235}. Let any one nucleus undergo fission. You know that the fission would produce about 3 neutrons. If the lump is large, the chance that these three neutrons would come out of the lump, without striking another nucleus of U^{235} on their way, is very low. In other words, when the lump is large, the three neutrons released in the first fission would likely produce three more fissions, releasing 3 x 3 = 9 neutrons. These 9 neutrons would split 9 more nuclei, releasing 9 x 3 = 27 neutrons and so on. If this process continues, billions of U^{235} nuclei would undergo fission in a very short time, releasing enormous amounts of energy. T at is how an atom c om exp o es.

If, on the other hand, the lump is too small, most of the neutrons released in fission would be able to escape, without inducing further fission. The reaction would, therefore, soon die out. The mass of such a lump is said to be below critical (or sub-critical), while the mass of the large lump is called a 'super-critical mass'.

How does one bring about an atomic explosion? Obviously, you cannot start with a super-critical mass of the fuel. The trick consists of taking several pieces of the fuel, each being sub-critical. These pieces are driven into one another using chemical explosives, so that a large super-critical mass is formed. In the bomb that was dropped on Hiroshima, two sub-critical masses of U^{235} were used.

T e plu onium bomb ha was exploded on Nagasaki worked on a different principle, called the principle of implosion. In the bomb, two hemispheres of Pu^{239} were placed face to face making one whole sphere. There was a small hollow space at the centre of this sphere, in which small capsules of beryllium and polonium were kept separately. At the time of implosion, these two elements would mix, generating abundant neutrons that would start off the fission. The two hemispheres of Pu^{239} were kept inside a hollow sphere of platinum which is a good reflector of neutrons. Explosives like TNT (Trinitrotoluene) were filled in the platinum sphere. Note that the total mass of Pu^{239} was about 5 kilograms, which was in fact a little less than its critical mass. However, when TNT exploded, the two plutonium hemispheres were compressed into each other. The increased density of plutonium made it super-critical. At the same time, the implosion crushed the capsules of beryllium and polonium, mixing these two elements and generating neutrons required for starting off the fission. Plutonium in the critical state with the abundant neutrons made the chain reaction grow in no time, and a huge amount of energy was released.

There is an important difference between U^{235} and Pu^{239} Plutonium is not found in nature. It is obtained as a by-product in a uranium (U^{235} + U^{238}) nuclear reactor. In other words, Pu^{239} is a man-made fuel.

The uranium and the plutonium bombs were fission bombs. Since their discovery in 1945, scientists have made a variety of atom bombs like fusion bomb (hydrogen bomb), cobalt bomb and neutron bomb.

A nuclear reactor works on the same principle as that of a fission bomb. However, the fission rate and, therefore, the rate at which energy is released are controlled in the nuclear reactor. In India, nuclear reactors are functioning at Tarapur in Maharashtra and at Ranapratap Sagar in Rajasthan. Another one is being set up at Kalpakkam in Tamil Nadu. India possesses the capability of exploding a nuclear device, as was demonstrated at Pokharan.

18. How is the depth of an ocean measured?

The old method of measuring the depth of an ocean was very simple. A heavy object, like an anchor, was tied to one end of a rope which was released from a ship floating in the ocean. This rope was marked like the measuring tape used by a tailor. As soon as the heavy anchor touched the ocean floor, the rope would no longer be taut. The marking on the rope then gave the depth of the ocean. This method was simple. It was, however, of no use for measuring very large depths. You know that oceans can be very deep, often deeper than 6 kilometres.

The modern method of measuring ocean depths is quite ingenious. Do you recall how often we tell distances in minutes? When you say that the school is ten minutes away from your house, you are describing the distance from your house to the school. Anyone who knows how fast you walk will know how much that distance is. The same principle is used to measure the distance from the surface to the bottom of the ocean. We will, of course, need someone to 'walk' this distance with a steady pace. The trick is to use sound to do the job.

You know that sound travels with a definite speed in any medium. In air the speed of sound is nearly 330 metres/sec., while in water the speed of sound is nearly 1460 metres/sec. We can produce some sound on the surface of the ocean and see how long it takes for the sound to reach the bottom. Since there is no one at the bottom of the sea, we have to measure the time taken by the sound to reach the bottom and come back to the surface again, after being bounced off from the bottom.

You can perform a simple experiment to see how the trick works. Have you ever been to a hilly area? Next time you go there, you can stand in front of a cliff and shout. The sound is bounced back by the cliff and you will soon hear your shout again. This is called an echo. The time between your shouting and your hearing the echo can be used to measure the distance between you and the cliff.

An instrument fixed to the bottom of the ship produces a sound. This sound goes through the water and is bounced back by the floor of the ocean towards the ship. The incoming sound is recorded by another instrument which is also fixed to the bottom of the ship. The time required by the sound to reach the bottom and come back multiplied by the speed of sound, gives twice the depth of the ocean. (Can you tell why twice?) This time is automatically recorded on a chart. Thus one can measure the depth of the ocean at different places.

However, ordinary sound is not convenient for this experiment. Let us see why. The sound waves produced by the device fixed to the bottom of the ship spread in all directions in water, so that very little of them actually strike the ocean

bed. The sound reflected from the ocean bed similarly spreads, and the echo received at the ship is extremely feeble. If the ocean is very deep, like the Pacific Ocean, the echo is hardly detectable. Ordinary sound is also absorbed to a large extent by water.

A different kind of sound, called the ultrasonic sound, is therefore used in these devices. Ultrasonic sound is a sound with very high frequencies. Sound that we hear, that is, the audible sound, has frequencies ranging from 20 to 20,000 cycles/second. Ultrasonic sound, on the other hand, has frequencies more than 20,000 cycles/second. This sound, therefore, cannot be heard. A beam of ultrasonic sound spreads much less than the ordinary sound, and therefore the echo received is much stronger. The ultrasonic sound is also less absorbed by water. Since the beam does not spread much, the ocean floor can be mapped accurately. The beam sees, at a time, only a small part of the ocean bed, and therefore detects even small ups and downs.

You may wonder, what would happen if a big obstacle like a huge fish or a submarine comes in the way of the beam? Would one then get a wrong estimate of the depth? Fortunately, different objects reflect sound differently. A skilled operator is able to notice the difference between the sound reflected by a whale and that reflected by the ocean floor. In fact, the knowledge of these differences enables him to detect sunken ships, swarms of fish, whales etc., which immensely increases the usefulness of the device.

Ships fitted with ultrasonic sound devices that produce short bursts (pulses) and record the echoes have been extensively used to chart the ocean floors in detail. You might like to know that the Arabian Sea and the Bay of Bengal have an average depth of only 4 kilometres, while the Pacific Ocean is very deep. At some places, it is over 11 kilometres deep!

19. How are large deposits of oil formed underground? How are these deposits discovered?

Oil is formed when dead plants and animals decay. When marine animals and plants die, they reach the bottom of the sea where bacteria cause their decay and produce oil.

As fresh layers of sediments are deposited on it, the oil is pushed into the small pores of rocks and spreads everywhere. Since fresh sediments are continuously deposited, the pressure on the oil increases and it is pushed deep underground, where it fills up all the available pores and cracks. This journey continues until the oil meets non-porous rocks through which it cannot pass. When the pressure increases even further, the oil begins to move upwards. When it finds its way upto the ground, we come to know that there is oil underground. Please remember that this process takes a very long time. The oil that we use now was probably formed several million years ago.

At many places the oil cannot find its way upto the ground. Remember, the oil has spread sideways also. If it is trapped between two layers of non-porous rocks, it can neither go downward nor upward. The oil, therefore, under increasing pressure, slowly finds its way to some huge gaps in rocks where it accumulates.

Now we know what to look for. We must look for a non-porous rock on top, a porous rock in the middle and a non-porous rock at the bottom. If there is a huge bulge in between, so much the better. But how do we know if such conditions exist underground?

To begin with, samples of porous rocks are analysed to check if there is organic material in them. If the rocks are rich in organic material, a drilling is undertaken.

Small holes are bored in the ground, just as you bore a hole in a piece of cork. The rock samples at various depths are then studied. If the conditions described above are present, the chances of striking oil are high.

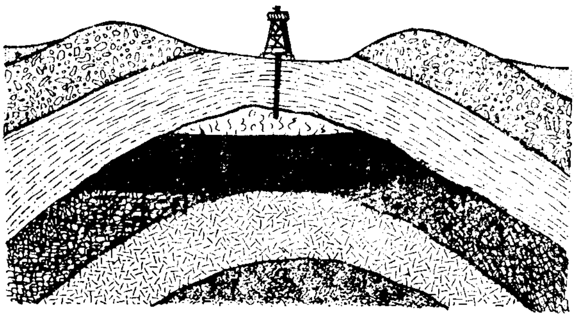


Fig. 12 Trapped oil (and gas) together with reservoir and cap rocks.

Small and controlled explosions are made on the ground. These explosions start shock waves that go underground and are reflected from the rocks deep below. The time taken by the waves to reach the rocks and come back is measured. These measurements give information about the nature and distribution of underground rocks, which in turn helps in locating the oil deposits. Measurements of Earth's gravity at different places also serve to find out the chances of striking oil reservoirs. Ma pi g of ti fi 'd over the Earth's surface is another method used for oil prospecting.

Even if you strike oil, it does not mean that the deposit will be large. The amount of oil is estimated before a well is drilled. Sometimes the estimates go wrong and the well soon dries up. Generally, if oil is found near the sea-coast, the chances of finding oil under the sea are also high. These days, it has been possible to rill for oil in the sea also.

You have probably heard that oil has been found near Bharuch and Cambay in the State of Gujarat. Recently, fairly large deposits of oil have been found under the sea near Bombay.

20. How and why does lightning strike?

Before we discuss this question, let us see how a lightning is produced. With the arrival of monsoon we often get thunderstorms, when flashes of lightning are followed by a roaring thunder. The lightning flashes are extremely bright. We are momentarily blinded by them. Some flashes go zigzag over a large part of the sky, and the lightning strikes the earth with an enormously loud thunder.

Clouds, as you know, contain a large number of extremely small water droplets. These water droplets are formed by water vapour condensing on dust particles. Some clouds, especially the thunder-clouds, are very huge — usually 2 to 3 kilometres across. They are also quite tall. A cloud that looks like a blue-black carpet from the ground is in fact a huge heap, nearly 10 to 12 kilometres thick. Obviously, the top of such a cloud lies in a very cold zone, where water is easily converted into snow or ice.

There are strong convection currents of air moving upwards and downwards in the thunder-clouds. These currents carry the water droplets up with them. When the droplets reach the upper part of the cloud, they turn into ice particles and start falling down. On their way down, they encounter water droplets that are being carried up by the air currents. The friction between the two streams produces electrical charges on the particles. (This is only a rough description. Really speaking, nobody knows the exact mechanism by which electrical charges are produced in clouds.) The ice particles that are coming down become negatively charged, while the water droplets going up acquire a positive charge. These two charges are, of course, equal in amount. As convection currents build up, a

large store of positive charge is accumulated at the top of the cloud while the bottom acquires an equally large store of the negative charge. Two factors help in building up these huge stores of charges. Since the air around the cloud is non-conducting, the charges do not leak away. Also, since the cloud is very huge, the opposite charges are stored in zones separated by several kilometres.

Well, then how does a lightning strike at all? Please remember that terms like a good conductor or an insulator are to be understood in a relative sense. Even the best conductor, say, a copper wire, does offer some resistance to the flow of electricity. (That is why it becomes hot.) Similarly, any insulator is good enough, only upto a certain voltage. The air surrounding the cloud is really a good insulator. However, the potential difference (voltage with respect to ground) in the cloud can sometimes reach a very high value, as high as, say, ten million (i.e., 10^7) volts. The resistance of the air then breaks down, the charges fly across a big spark, and a large current begins to flow. In which direction will this current flow? Sometimes the sparking occurs within the cloud, sometimes between two clouds and, on some occasions, between the cloud and the earth. How can the current flow to the earth?

There is one important factor which can lead to a discharge towards the ground. The negative charge accumulated at the bottom of the cloud induces a positive (opposite) charge on the ground below it. As you know, there is attraction between unlike charges. As the cloud charge makes its way towards the earth, the attraction increases and, therefore, the induced charge is pulled up. When both these charges meet, a clear path is created for the cloud charge to flow towards the ground. This flow is very fast. It lasts only for a fraction of a second.

A large amount of charge flowing in a short time gives rise to both the effects of a lightning; the brilliant spark and the loud thunder. The air molecules in the path of the current are heated to such an extent that they emit light and the path is seen as a bright streak. The sound, as you know, is produced only when something vibrates. Since the air in the path of the lightning is heated suddenly, there is an instantaneous expansion of air. This sudden expansion leads to shock (pressure) waves. The air around the discharge region moves in to fill the space created by the expanding air. These sudden movements (vibrations) of air produce the thunderous roar which you hear.

You may wonder why the thunder continues for a while instead of producing one big bang? Well, there are other clouds in the sky that reflect these sound waves. Intense sound waves produced, as stated above, travel in all directions. The waves coming directly towards us enable us to hear the first big sound. Soon the waves that are reflected from various other clouds also begin to reach us. These are echoes of the original sound. Naturally, all the echoes do not reach us at the same time. Those coming from neighbouring clouds reach us earlier than those coming from the clouds farther away. That is why we keep hearing the thunder for some time.

What happens when lightning strikes the earth? You might have read reports describing destruction of buildings or tall trees in villages. Please remember that lightning occurs when voltages like some millions of volts are built up. The current in a typical lightning discharge is also very large, of the order of, say, 30,000 amperes. You can get some idea of this enormous release of energy, if you remember that our ordinary household wiring carries only a few amperes at 230 volts. Even then, a short circuit sometimes produces sparks and can lead to a lot of damage. The scale on which nature operates is truly enormous!

These days a simple device is used to protect buildings from a possible lightning discharge. You might have seen a pointed copper rod with spikes, erected on tall buildings and factories. This rod is earthed, using a wide and thick copper strip. If lightning strikes, the rod and the copper strip provide an easy path through which the current passes harmlessly, and the building is saved.

21. How are mineral deposits found in the earth?

Minerals are usually found in deep mines, that is, inside the earth's crust. How did the ancient man come to know that he should dig deep at a particular place to find, say, nickel? Obviously, the ancient man knew nothing about these hidden deposits.

However, he soon learnt to use the minerals that were found easily in the exposed soil and rocks. For example, man learnt to use rocks rich in iron, and the iron age emerged. Similarly, large deposits of coal were found in England in the hills near Newcastle. Gold was similarly discovered in shallow waters of some rivers. Soon, however, these deposits were exhausted. Moreover, with increasing industries, man's need for many types of minerals also increased. He soon discovered the treasures hidden underground.

How does one go about searching for the stocks of any given mineral? The methods depend upon the properties of the mineral. For example, suppose we are looking for stocks of iron. We know that iron oxide ($Fe_3 0_4$) is magnetic. If the rocks contain large percentages of magnetic ores of iron or of nickel, the earth's magnetic field at that place will show a deviation from the normal value. If we are looking for iron, we should study the variation of the magnetic field near the prospective site.

The principle illustrated above can be extended to cover many situations. For example, you know that the earth exerts a gravitational pull on all objects. If the earth were a homogeneous (i.e., similar everywhere) and perfect sphere, its pull would have been same everywhere. However, the earth is not all that perfect. In a few places the crust is thick; in some other places it is thin. In some places, the crust contains very heavy (dense) metallic rocks, while in some other places it contains porous sandstone. A detailed study of the earth's gravitational pull all over the globe gives useful hints about the possible locations of mineral deposits.

With the advent of atomic energy and nuclear reactors, our need for radioactive minerals has also increased. As you know, a radioactive substance emits radiations. If you wish to detect radioactive minerals, you carry special instruments to detect these radiations. There is one more clue which enables us to spot radioactive minerals. These minerals emit radiations, that is, energy. When this energy is absorbed by the surrounding material, the local temperature of the region goes up. If, in the earth's crust, you look for warm regions surrounded by relatively cooler ones, you are likely to discover deposits of radioactive minerals.

The fact that different materials have different properties can be exploited in a variety of ways. For example, you know that during an earthquake or an explosion, shock waves are produced. These waves travel through different rocks with different speeds. A careful study of how these waves travel through different layers and portions of the earth's crust is very useful in detecting the presence of metallic rocks (rocks containing metals).

This discussion shows that if we wish to satisfy our growing needs for minerals, we should carefully study the earth's crust. In India, the Geological Survey of India, Mineral Exploration Corporation and the Atomic Minerals Division of the Department of Atomic Energy and some departments of Geology are doing this job. Carefully prepared maps, showing the magnetic fields, local temperatures, gravitational pull etc., are available. These charts have enabled us to discover deposits of iron, manganese and other metals. You might have heard that radioactive prospecting often reveals deposits of uranium and other radioactive minerals.

An important aid to such prospecting has been provided by the satellite. The satellite is able to sample a large part of the earth's surface and transmit the data which can be analysed quickly using a computer. In fact, one of the American satellites was called ERTS, the Earth

Resource Technology Satellite. In India, a programme to build such satellites has been undertaken and much progress has been made in remote sensing, that is, in interpreting the data sent by the satellite.

Apart from these systematic efforts, some mineral deposits are discovered accidentally. For example, people digging for some entirely different purpose (say, a well) may strike a rich deposit of some mineral. In that case, careful prospecting is immediately undertaken to study how large the deposit is. If it is found that the deposit is large enough, excavation is continued. Otherwise, the site is abandoned.

22. How were the oceans formed?

Nearly three-fourths of the earth's surface is covered by the oceans. The rest is land that we live on. Also, the earth has a dense atmosphere consisting mainly of nitrogen and oxygen. The rest of the atmosphere is made of carbon dioxide, water vapour, argon, etc. We might be tempted to believe that the earth has always looked like this, ever since it came into being.

However, this is not true. The earth was born nearly 4 to 5 billion (a billion is nine zeros after 1) years ago in a very hot state. Whatever gaseous enveolpe it had was quickly lost, because of the high temperature. The earth soon became bare of atmosphere.

However, as the earth cooled, it developed a solid crust of rocks. When rocks solidified, gases like nitrogen, trapped in them, were released. Also, most of the mountains on the earth were then active volcanoes that erupted frequently. During volcanic eruption, nitrogen, carbon dioxide and water vapour were released. The earth thus created its own atmosphere. Since the earth was now cooler, this new atmosphere was not lost, but most of it was retained.

As the earth cooled further, the water vapour in the atmosphere condensed into water. In other words, it began to rain. Unlike the seasonal rains that we call monsoon, this rain lasted several thousand years. The rain-water accumulated in low lying areas and formed the oceans.

You may wonder, how do we come to know about these ancient events? It is really a guess based on the facts that we know today. For example, even today when a volcano erupts, it releases nitrogen, CO_2 and water vapour. This observation gives strength to our guess.

Do you know where the atmospheric oxygen came from? It was not there initially. Some of it might have come from the sea-water that could have been decomposed by the strong rays of the sun, which were rich in ultra-violet light in those days (say, 3.5 to 4 billion yeras ago). Most of the oxygen, however, was generated by the plants. You know that plants absorb carbon dioxide and release oxygen back in the atmosphere, during photosynthesis.

23. What causes a storm?

A light breeze on a hot summer day is very pleasant. However, when winds move very fast, they can cause much damage. Sometimes the wind gets a circular motion also. Winds rapidly whirling in circles and advancing with a high speed are known as cyclones. Cyclones can be disastrous.

When the air pressure at one place is lower than the air pressure at another place, air begins to move from the higher pressure area to

the lower pressure area. Such conditions usually arise in summer when the land gets considerably hotter than the sea. The air above the hot land is heated and therefore rises, creating a zone of low pressure. Comparatively cooler air above the sea moves towards this zone. You know that winds coming from the sea often bring rain-clouds with them. For example, the monsoon winds bring us rain.

Remember that the air above the sea is not uniformly hot or cold everywhere. Thus, there are winds on the sea also, moving from zones of high pressure to zones of low pressure. Similarly, there are winds on the land too. Such winds usually make dust storms. In north India, especially in some parts of Rajasthan and Gujarat and in Delhi, dust-storms occur quite frequently in summer.

As the low pressure zone moves, the wind changes its direction. As a rule, big storms begin on the sea and move towards the land. That is why people in the coastal region suffer more from the storms. These storms seldom reach the regions far away from the sea-coast.

What really matters is the speed of the winds. The afternoon sea breeze has a speed of only 20 to 30 km. per hour or less. Such a breeze is quite pleasant. When the wind speed exceeds 50 to 60 km. per hour, one begins to notice its destructive power. In a typical storm, winds move at 80 to 100 km. per hour. Such winds can uproot trees, blow off house-tops, raise huge waves on the sea and sink small ships and boats.

Cyclones are even more dangerous. They are formed in tropical regions on the seas, when several zones of low and high pressure are created. Strong winds moving in opposite directions come together to build a very strong wind moving in a circle, which is called a cyclone. Often, these winds move in a big circle with a speed exceeding 200 km. per hour. When a cyclone reaches the sea-shore, it can cause enormous damage, as it recently did in Andhra Pradesh. Sometimes rain clouds are trapped in a cyclone. Such a cyclone brings torrential rains and lightning with it.

Cyclones are created on the land also. Sometimes thunderstorms create a small cyclone in the clouds. Soon this cyclone descends on the ground, bringing rain. Although such a cyclone is small in size and does not last long, the winds move with a very high speed (say, 200 km. per hour) while the cyclone lasts. Such cyclones occur in Australia and in the United States of America.

These days we know a lot about cyclones. Artificial satellites, called 'weather satellites', give us precise information about where the low pressure zones are located. The information about the location of such zones and the speed with which they are moving, enables us to predict when and where the cyclone will hit. Even though we cannot stop the cyclone, we can use this information to reduce the damage to the property and, above all, to save precious lives.

24. Why does the rising or the setting sun look elliptical?

A lot of interesting things happen due to the earth's atmosphere. The rising sun looks brilliant orange, the sky looks azure blue, the stars twinkle at night, alluring mirages occur in hot deserts—all these are atmospheric phenomena. The sun appearing to be elliptical near the horizon is also an atmospheric phenomenon.

You know that light travels in straight lines. You also know that a ray of light bends when it enters from one medium (substance) into another. This phenomenon is called refraction of light. A pencil dipped in a glassful of water looks broken because of refraction. Please remember two things about refraction. Light bends

m[illegible] if th[illegible] o[illegible] m[illegible]ia [illegible]r more. Secondly, a ray of light incident normally on a medium does not bend at all. As the angle of incidence increases, however, the ray bends more and more.

The earth is surrounded by a thick blanket of air, called the atmosphere. The atmosphere is dense near the groun an ecomes t inner as we go up. The rays of the sun, travelling a long way through empty space, enter the earth's atmosphere. The path of a ray of light begins to change, as the ray starts streaming down through the atmosphere. Remember, the light rays encounter thin atmosphere in the beginning which becomes denser as the rays travel downwards towards the earth. Finally the rays enter our eyes and we see the sun. Please note that the direction in which the rays enter our eyes is quite different from their original direction before entering the atmosphere. You know that we see the object in the direction in which light rays from the object enter our eyes. As a result of the change in the direction of the sun's rays, we see the sun shifted upwards from its actual position. (By looking at the sun, we only know where it is seen and not where it actually is). This means, we see the sun already risen in the east, when, in fact, it is still below the horizon. Similarly, we see the sun about to set in the west, when, in fact, it has already gone below the horizon.

We now know that the path of the sun's rays changes continuously as they come through the atmosphere. This bending, however, depends upon the angle of incidence. The rays coming from the overhead sun are incident normally on the atmosphere and, therefore, do not bend. The rays coming from the rising or the setting sun make the largest angle of incidence with the atmosphere. Therefore, these rays bend to the maximum extent.

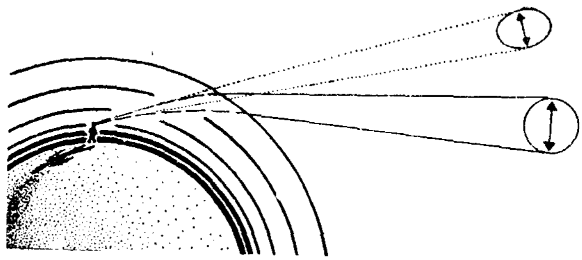


Fig. 13 *The rising sun looks elliptical. (It is also seen displaced from its actual position.)*

Light comes to us from every point in the circular disc of the sun. Consider the two extreme points, the lowermost and the uppermost points of the solar disc. When the sun is near the horizon, the lowermost point is nearer the horizon than the uppermost point, by the apparent diameter of the disc. The ray of light coming from the lowermost point bends a little more than the one coming from the uppermost point. As a result, both the points are shifted up.Therefore, we see the entire solar disc shifted a little up in the sky. However, the lower point is shifted a little more than the point at the top. The solar disc, therefore, looks slightly compressed into an elliptical shape. The elliptical disc looks compressed in the 'vertical' direction. That is, the major axis of the ellipse looks parallel to the horizon. As the sun rises up in the sky, this effect decreases rapidly and the disc begin to look circular.

25. What is a comet?

To see the sun, the moon, the planets and the thousands of stars in the sky is nothing new. We see these objects almost every day. Sometimes, though very rarely, we see a queer-looking object in the sky. It looks like a bright ball with a long tail. This spectacular but rare visitor is called a comet.

You know that our solar system consists of a few planets moving round the sun. The planets

move in elliptical orbits. The sun is a huge massive star at the centre of the solar system. It is one of the many stars in our galaxy which we call the 'milky way'. Perhaps you may not know that there are many comets in our solar system. Then why don't we see them as often as we see the planets and the moon?

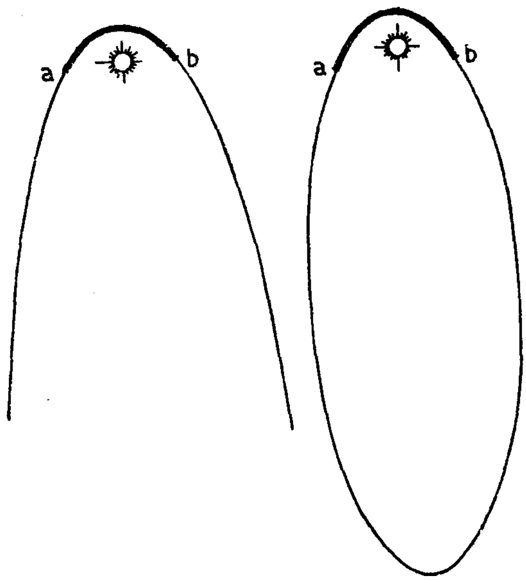


Fig. 14 Comets have either parabolic or elliptical paths. Segments 'ab', on which comets become visible to us, look alike for both the paths.

Some of the comets have elliptical paths. These ellipses are huge and quite elongated. That is, one of their axes, called the major axis, is very long, and the other one (minor axis) is relatively quite small. Some of the comets, however, move along parabolic paths. You know that a parabola, unlike an ellipse, is an open figure. Therefore, a comet moving along a parabolic path comes in its lifetime only once near the sun. That is why, once we see such a comet, we do not see it again. It visits us only once. It goes round the sun and vanishes forever in space. On the other hand, comets moving along elliptical paths can be seen again. Since the ellipses are quite huge, these comets take a long time to go round once in their orbits. Therefore, they visit us only after many years.

Comets are not like the sun or the stars. They do not emit light. They are rather dead objects like planets or the moon. They are seen only in the light of the sun. That is why they become visible to us, only when they come near the sun. As they go away from the sun, they become fainter and ultimately vanish from our sight. Please remember that every comet, moving along its orbit, approaches he sun, goes round the sun and then travels away. Once you see a comet, you keep on seeing it for days together. And remember that we can see a comet either a few hours before sunrise or after sunset. Some of them can be seen even during the day. Please don't try to look for a comet in the midnight sky!

There is a problem about comets. You know that some comets move along parabolas and some along ellipses. However, we see only that part of the path which lies near the sun. (The parts on which we can see the comet are shown as 'ab' in the figure for a parabola and an ellipse.) These parts look very much alike. Therefore, it becomes difficult to decide whether the comet is trave ng a ong an e pse or a parabo a. I , by some means, we do find out that the comet is indeed moving along an elliptical path, we can also tell the precise time when it will visit us next.

Really speaking, a comet as such has no tail. Every comet is simply a huge ball of particles. The ball mainly consists of ice particles and the frozen particles of methane, ammonia, etc. When this bunch, moving along its course, comes near the sun, it acquires a long tail as a result of solar radiation. You know that the sun emits enormous amounts of energy and charged particles. The solar radiation pushes the bunch in the opposite direction, ejecting a stream of particles. This stream is what we call the tail of the comet. Naturally, we see the tail shoot out in the direction opposite to that of the sun. The particles in the tail are very thinly spread out. The tail, therefore, looks transparent and we can easily see through it. The tail is very long.

Some comets throw off tails as long as 4 to 5 million kilometres or more out in space. It is truly a gigantic affair!

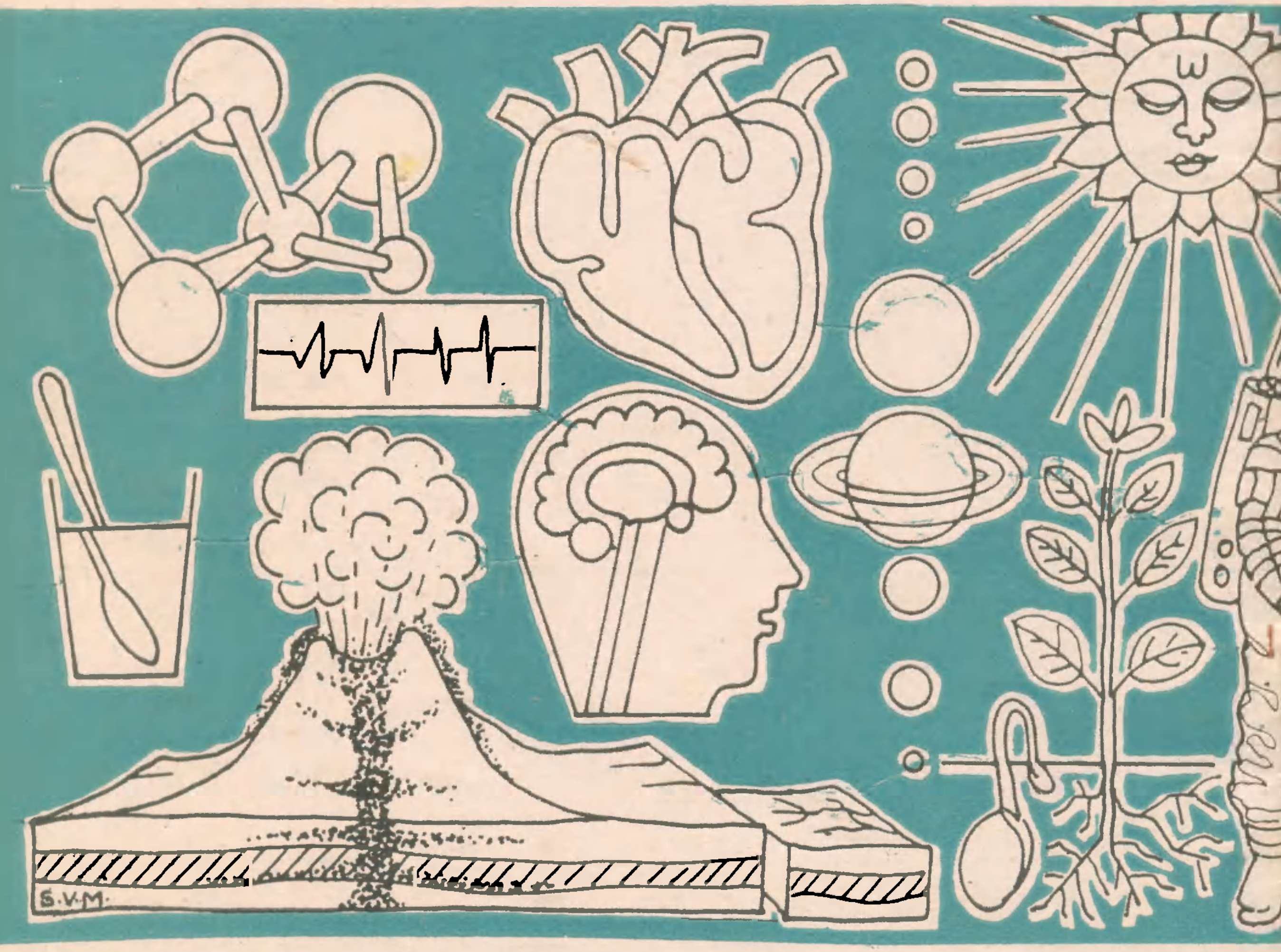
Sir Isaac Newton, the famous scientist, saw a comet in 1680. One doesn't know, however, whether the path of the comet was parabolic or elliptical. If we assume that the comet was indeed moving along an elliptical path, it is estimated that we will be able to see it again in 2255. It means, this comet takes about 575 years to move round once. If we go backwards from 1680 and keep subtracting 575, we arrive at the year 45 B.C.. Julius Caesar was killed in 44 B.C.. One can, therefore, say that possibly there was a comet in the sky when this great historical figure was assassinated.

Scientists tell us that we will be seeing a comet in 1986. This comet was discovered by Halley in 1682 and was named after him. Halley's comet has an elliptical path and takes about 76 years to complete one revolution round the sun. It was seen earlier in 1910.

People often believe that comets are evil things and that a comet spells disaster to the country or to the ruling king. However, such a belief has no scientific basis. Please remember that disasters did not occur, every time a comet appeared in the sky. Moreover, a lot of calamities occurred when no comet was at all visible in the sky. Therefore, if, on some rare occasions, comets and calamities did occur together, they should be considered as no more than mere coincidences.

How and Why in Science is a novel way of developing a scientific attitude to the world around us. It answers questions based on everyday observations of things and explains scientific principles by practical demonstrations of their operation in matter around us.

The questions in this book were raised by children, and are answered for them in a simple manner with graphic illustrations by highly qualified scientists.



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